PROGRESSIVE TECHNICAL SERIES

JUNIOR ELECTRICITY

GORDON DARLING

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PROGRESSIVE TECHNICAL SERIES

JUNIOR ELECTRICITY

A Course of Practical Lessons in
ELEMENTARY ELECTRICITY
For Grades VII., VIII. and IX.

BY

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FOREWORD

The trend of modern education demands that the teaching of any scientific subject should be approached by simple preliminary stages. In a preliminary science course, simple experimentation should assume the major part, the theoretical material being arrived at by deduction and conclusion. In a subject like Electricity, it is bad pedagogy to start with theory. An early educational reformer once said, "We learn by doing." He might have also remarked that we learn best by making mistakes.

In common life today we are so surrounded with actual examples along the science of electricity, that the average boy accepts them all as incidentals and commonplace. As soon as a small boy can reach a switch or a push button, he is anxious to see what happens. With his years his actual experience grows. He knows that certain actions of his, in connection with electrical devices, have certain effects. He does not know why.

In this book he begins to know why. He likes to tear a clock to pieces to see why it works. He sees electricity working every day, and Junior Electricity opens the hitherto closed book. But instead of getting knowledge by breaking up things, he is educated by building up.

The author has been fortunate in having had a long experience in teaching boys the rudiments of electricity. He has found out that the old approach through the text book and blackboard is futile, and he has also found out that the best method is by actual doing.

No great stress is laid on the theoretical side. The theory, meantime, is incidental. Through a series of simple projects the boy is led along the path of discovery, and the results are stored for the coming theoretical lessons.

When he takes up advanced work he knows what a current is. He has worked with it. He knows what he can actually perform with it. Therefore he welcomes it in its new guise as a friend, and furthers his acquaintance with it.

I have watched the experiment in the school. It is now past the experimental stage, and we accept this method of teaching preliminary electricity as being eminently practical, sound pedagogically, and intensively intriguing to the boy.

JAS. G. SINCLAIR,
Principal
Vancouver Technical School.

March, 1935.

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PREFACE

The aim of these lessons is to acquaint the pupil with electricity in its more simple applications; to familiarize him with the utility of various electrical appliances and fittings, and to develop safe, careful and neat habits of working. They are adapted particularly to the Junior High School programme.

Electrical theory is a very abstract subject. These lessons are designed to give a concrete presentation with the use of such material as may come within the experience of the pupil. The idea is to start him on some practical job with as little explaining as possible, and to let his curiosity and interest in the theory be roused through the work. A simple lesson is associated with each job so that the electrical principles are easily conceived in a graded sequence.

Lessons I. to XVIII. are suitable for Grade Seven, Lessons XIX. to XXXI. for Grade Eight, and XXXII. to L. for Grade Nine.

The author wishes to express his appreciation of the assistance given by Mr. John Kyle, Organizer of Technical Education for the Province of British Columbia, and also Mr. Stanley J. Wright, Assistant Instructor in the Electrical Department of the Vancouver Technical School.

G. D.

Vancouver Technical School,
Vancouver, B. C.
March, 1935.

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JOB I. SPLICING ANNUNCIATOR WIRE

Proposal. To make splices in annunciator or bell wire.

Requirements. Six short pieces of annunciator wire.

Procedure.

(a) **The Western Union Joint.**

Unwind about two inches of the cotton yarn. There are two layers wound in opposite directions. Tie the ends together in a tight double knot and cut off the loose ends neatly. Wrap the wires neatly around one another as shown in figure. Make at least six turns on each end and snip off the ends with cutting pliers. The joint should be mechanically tight so that the wires will not move when forced one way or the other. For ordinary bell circuits it is unnecessary to solder or insulate the joints with tape.

(b) **To make a Tap Splice.**

Prepare the end of the branch wire as before. Bare the line wire for about an inch and tie up loose ends. Wind the end of the branch wire around the line wire as shown in figure.

(c) **Rat Tail Splice.**

Prepare the ends as in (a) and twist them together, bend over the ends and trim off with cutting pliers.

NOTE: For bell work this splice may be used instead of the Western Union Joint.

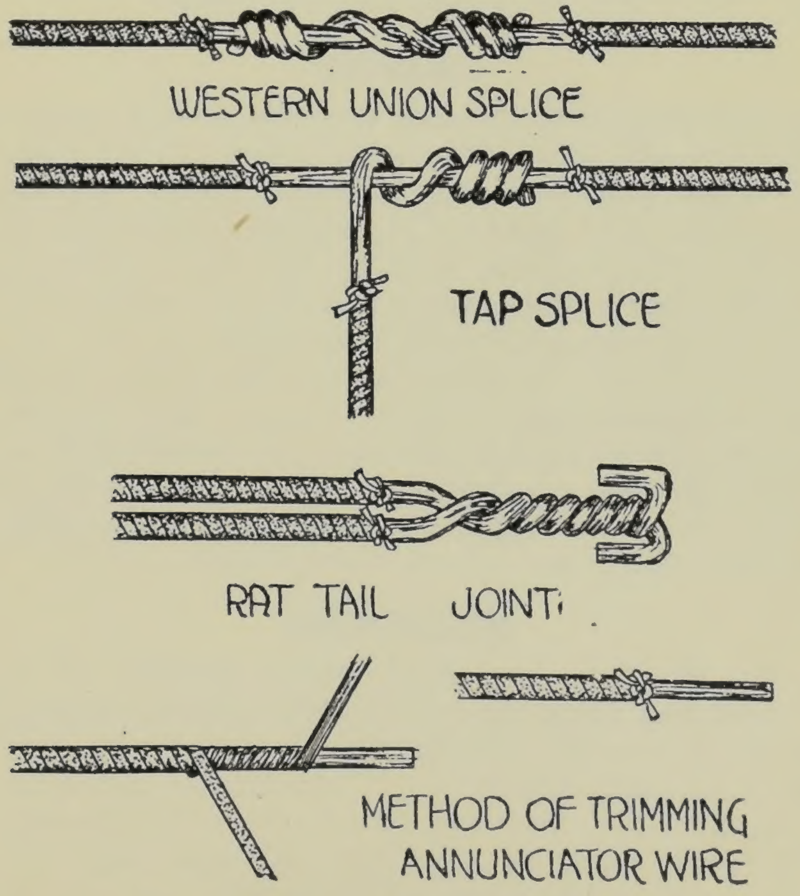


Fig. I. Splicing Annunciator Wire.

JOB II. SIMPLE LIGHTING CIRCUIT.

Proposal. To connect up a small electric lamp, receptacle, push button and dry cell.

Requirements. One 1½ volt lamp and receptacle, one push button, one dry cell, some bell wire.

Procedure.

1. Examine the lamp, button and dry cell.
2. Arrange them in neat order on your wiring board.*
3. Wire up neatly as in sketch (cleats or staples may be used).
4. Test your circuit by pressing the button and lighting the lamp.

*NOTE: See Fig. XXXV. for detail of wiring board.

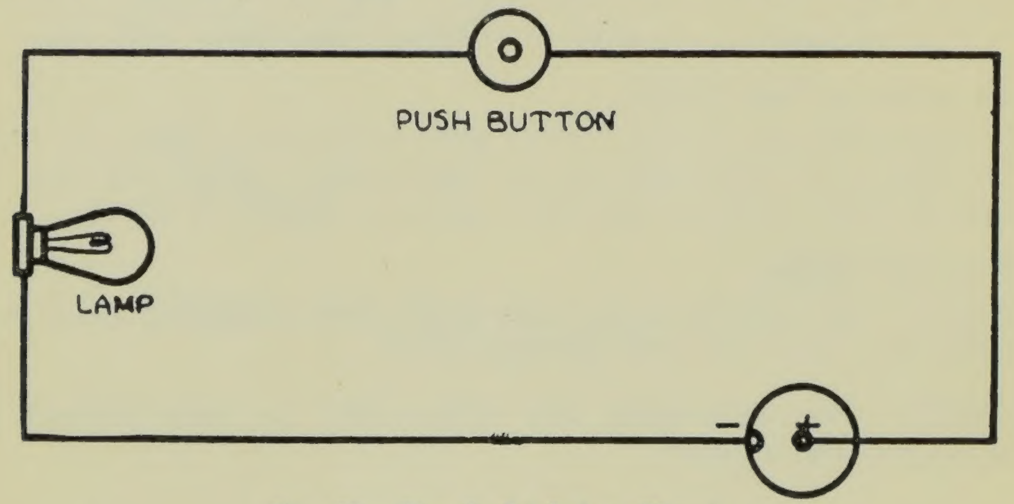


Fig. II. Simple Lighting Circuit.

LESSON.

It will be observed from this job that the circuit starts at the middle terminal of the dry cell called the positive (+); then goes through the push button and the lamp back to the negative (—) terminal of the dry cell which is on the zinc shell. This makes a complete loop from one point around the various parts back to the same point again. Thus a **"circuit"** may be defined as a path consisting of conductors which forms a loop around which the electricity may flow.

You will notice that the lamp lights only when the push button is pressed. That is because the circuit is kept open at the push button and is completed only when it is pressed. A circuit that is not complete is called an **open circuit.** A **closed** circuit is one which is unbroken all the way around. If you examine the push button you will notice that it is a switch which opens and closes the circuit.

QUESTIONS.

1. Why was the lamp not alight all the time?
2. Why does the lamp light when the button is pressed?
3. What is an electric circuit?
4. What is an open circuit?
5. What is a closed circuit?
6. Which is the positive terminal of a dry cell?
7. Which is the negative terminal?
8. Which direction does the current travel around the circuit?

JOB III. CONDUCTORS AND NON-CONDUCTORS.

Proposal. To test different materials to ascertain whether they are conductors or non-conductors.

Requirements. Dry cell, 1½ volt lamp and receptacle, wire, and several short pieces of material for testing, such as a nail, pieces of lead, rubber, zinc, glass, etc.

Procedure. Connect up the dry cell and lamp as shown in sketch. Touch the two ends A and B together and the lamp should light. This is to test the circuit. Now connect the two ends A and B to the nail. If the lamp lights it will show that iron is a good conductor. Repeat with other materials and make a list of five good conductors and five non-conductors.

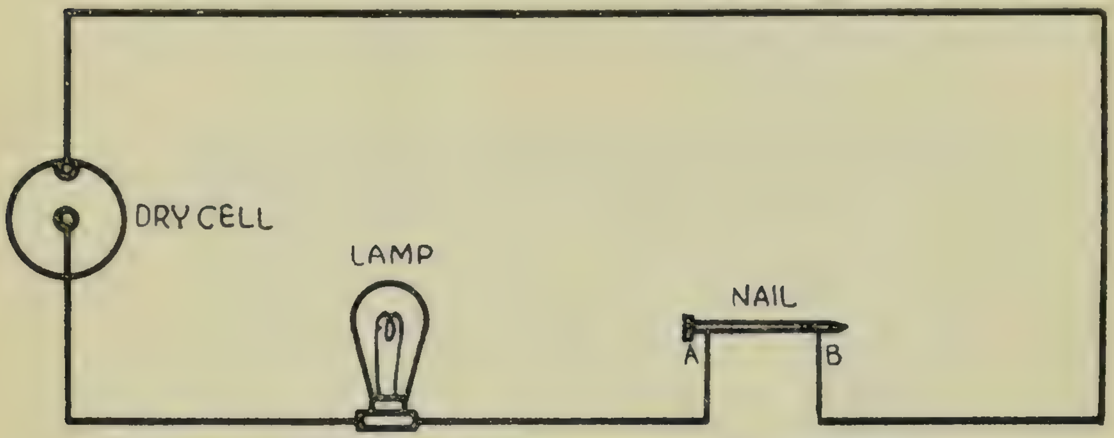


Fig. III. Test for Conductors and Non-conductors.

LESSON.

When we think of a current of water we imagine water in motion. In the same way an **"electric current"** is electricity in motion. We measure the electric current in **"amperes."** The greater the flow, the greater will be the amperes passing through the circuit. From this job you will have noticed that electric current passes readily through some substances. These are called **good conductors.** Silver is the best conductor known, but as copper is nearly as good and much cheaper, all our electric wires are made of pure copper. Many materials will not conduct electricity at all. These are called **non-conductors** or **insulators.** Air is a good insulator but electric wires are generally covered with insulating material such as rubber or cotton yarn. This prevents anything from coming in contact with the wire.

QUESTIONS.

1. What is an electric current?
2. What is the unit for measuring electric current?
3. What is a conductor of electricity?
4. What is a non-conductor?
5. Why are electric wires insulated?
6. Why are electric wires made of copper?
7. What is the best conducting material known?
8. Is air a good insulator?

JOB IV. SIMPLE BELL CIRCUIT.

Proposal. To connect up an electric bell (or buzzer), push button and dry cell.

Requirements. One bell (or buzzer), one push button, one dry cell, some bell wire.

Procedure.

1. Examine the bell, button and dry cell.
2. Decide where and how you are going to arrange them on your wiring board.
3. Fix them in place with screws.
4. Wire up neatly as in sketch (cleats or staples may be used).
5. Test your circuit by pressing the button.

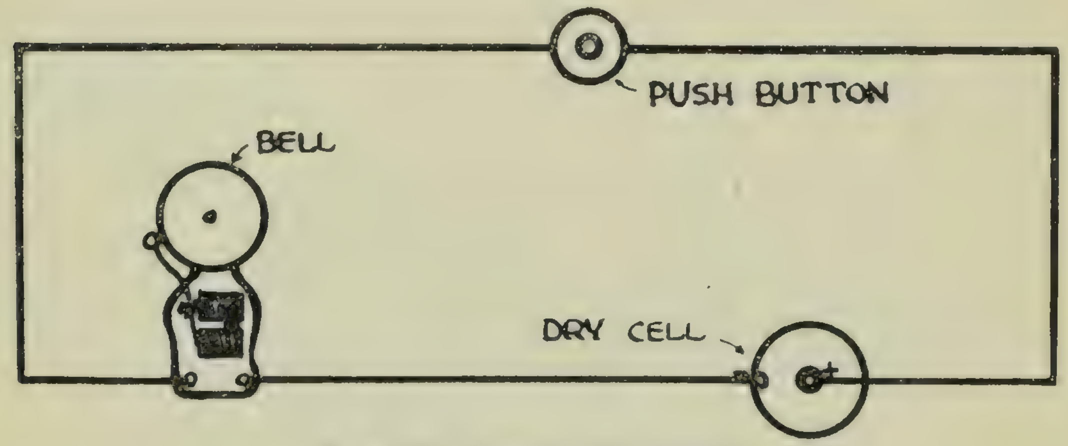


Fig. IV. Simple Bell Circuit.

LESSON.

Water is made to flow through a pipe, hose or other water conductor by the water pressure produced by gravity or by a pump. In the same way in an electric conductor the electric current (amperes) is made to flow by electric pressure. Electric pressure is called **"voltage."** It may be produced by a dry cell which gives 1½ volts or by a storage cell which gives 2 volts, or by a generator. Generators are of all sizes and may give as high as 10,000 volts or even more.

QUESTIONS.

1. What causes water to flow in a water pipe?
2. What makes the electric current flow around the electric circuit?
3. What is voltage?
4. What is the voltage of a dry cell? of a storage cell?

JOB V. ONE BELL AND TWO PUSH BUTTONS.

Proposal. To operate an electric bell from two push buttons.
Requirements. One dry cell, two push buttons, one bell, some bell wire.
Procedure.

1. Arrange bell, push buttons and dry cell neatly in position on wiring board.
2. Wire up connecting buttons in parallel as in sketch. (Use branch splice if necessary as in Lesson I.)
3. Now remove buttons and rearrange them in series as in sketch for series buttons.
4. Wire up again and study the effect.

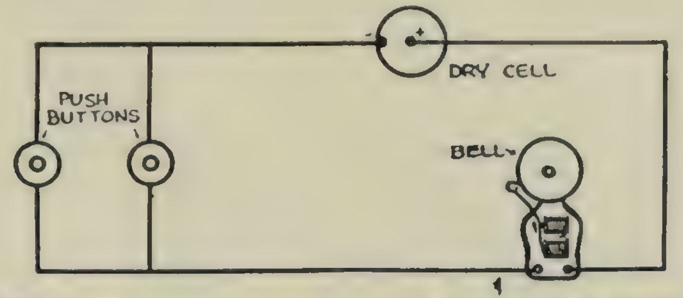


Fig. V. (a) Push Buttons connected in parallel to operate a bell (correct method).

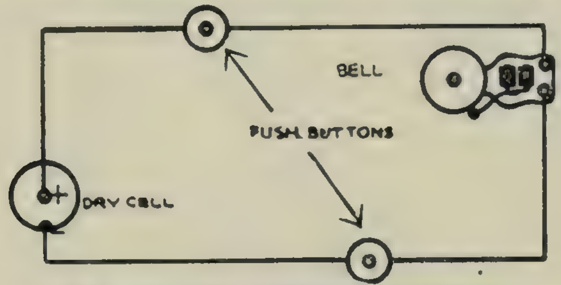


Fig. V. (b) (Wrong method).

LESSON.

In the first circuit the buttons are connected in parallel. A **"parallel"** circuit is one in which there are two or more separate paths which the electric current may take. The bell (or buzzer) may now be operated independently from either button. This is the proper way to connect such a circuit.

In the second circuit the buttons are connected in series. A **"series"** circuit is one in which the current goes through one part and then through the next part following. There is only one path for the current. The bell (or buzzer) can only be operated now by pressing both buttons at the same time. This is NOT the correct way to connect buttons although many pieces of apparatus are connected in series; for example—In Lesson II. the cell, button and lamp are all in series with one another forming one path.

QUESTIONS.

1. What are two different methods of making electrical connections?
2. How are two or more push buttons connected to operate the same bell?
3. In a two button connection how many separate paths are there for the current?
4. What is a parallel connection?
5. What is a series connection?

JOB VI. TWO BELLS (OR BUZZERS) OPERATED FROM ONE PUSH BUTTON.

Proposal. To operate two bells (or buzzers) so that when the push button is pressed, both bells will ring.

Requirements. Two bells (or buzzers), one push button, one dry cell, wire.

Procedure (PART ONE).

1. Study the diagram carefully. Notice that the two bells are connected in **parallel.** Trace the paths of the current starting at the positive terminal of the dry cell. There are two paths, one through the first bell, and another through the second bell. 2. Now arrange your materials on the wiring board in neat order. Screw them into place. 3. Wire up according to the diagram. 4. Test out by pressing button.

(PART TWO).

1. Draw a diagram of two bells (or buzzers) connected in **series.** Have this checked by the instructor. 2. Wire up according to your diagram. 3. Test out and compare the effect on the bells with the parallel connections.

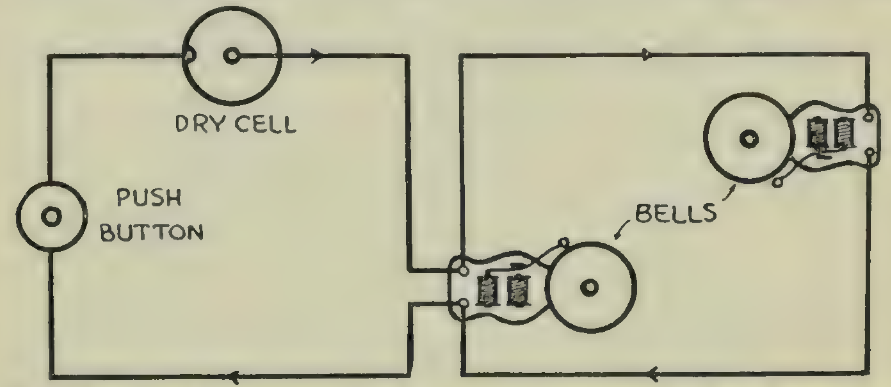


Fig. VI. Two bells connected in parallel, operated by one push button.

NOTE.—Two wires are shown connected to same terminal of bell. This is not usual in trade practice but is done to avoid splicing, and makes for economy in wire in school work.

LESSON.

When several bells and buttons are operated in one system by the same battery of cells, the following rules are of great assistance in wiring:—

Rule 1. Connect one terminal of the battery to all bells.

Rule 2. Connect the other terminal of the battery to all push buttons.

Rule 3. Connect each button to the bell it is intended to operate.

This method of wiring will result in each bell forming a path in **parallel** with the others. A system of this kind is used in a school having a number of programme bells operated by one push button in the principal's office or by a master clock.

QUESTIONS.

1. When one bell is operated by two push buttons, are the push buttons connected in series or parallel?
2. When two bells are operated by the same push button, are the bells connected in series or parallel?
3. Make a sketch of three bells operated by one push button and dry cell.
4. Do ordinary bells operate satisfactorily when connected in series?

JOB VII. FRONT AND BACK DOOR BELL CIRCUIT.

Proposal. To wire up a bell and buzzer so that the bell rings from the front door push button and the buzzer rings from the back door push button.

Requirements. One bell, one buzzer, two push buttons, wire and dry cell.

Procedure.

1. Arrange material neatly on wiring board.
2. Screw them in place.
3. Wire up according to diagram.
4. Test out.

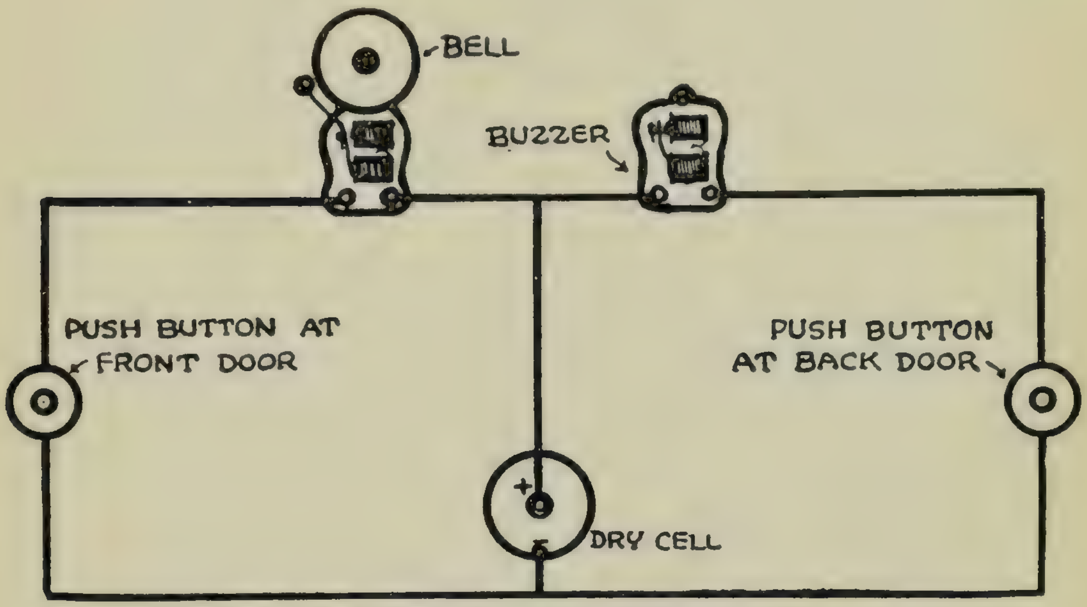


Fig. VII. Front and back door bell circuit.

LESSON.

This circuit is connected according to the Wiring Rules of Lesson VI. A bell and a buzzer are used so that one will understand by the audible signal whether to answer the front door or the back door. There are really two parallel circuits connected to the same dry cell. It is well to follow the paths of the current around each circuit and satisfy yourself of the truth of this statement.

QUESTIONS.

1. Why do we not use two bells in the front and back door circuit?
2. How many circuits are there in this arrangement?
3. Show by a diagram how more than two circuits may be operated by the same dry cell.

SERIES AND PARALLEL CELLS

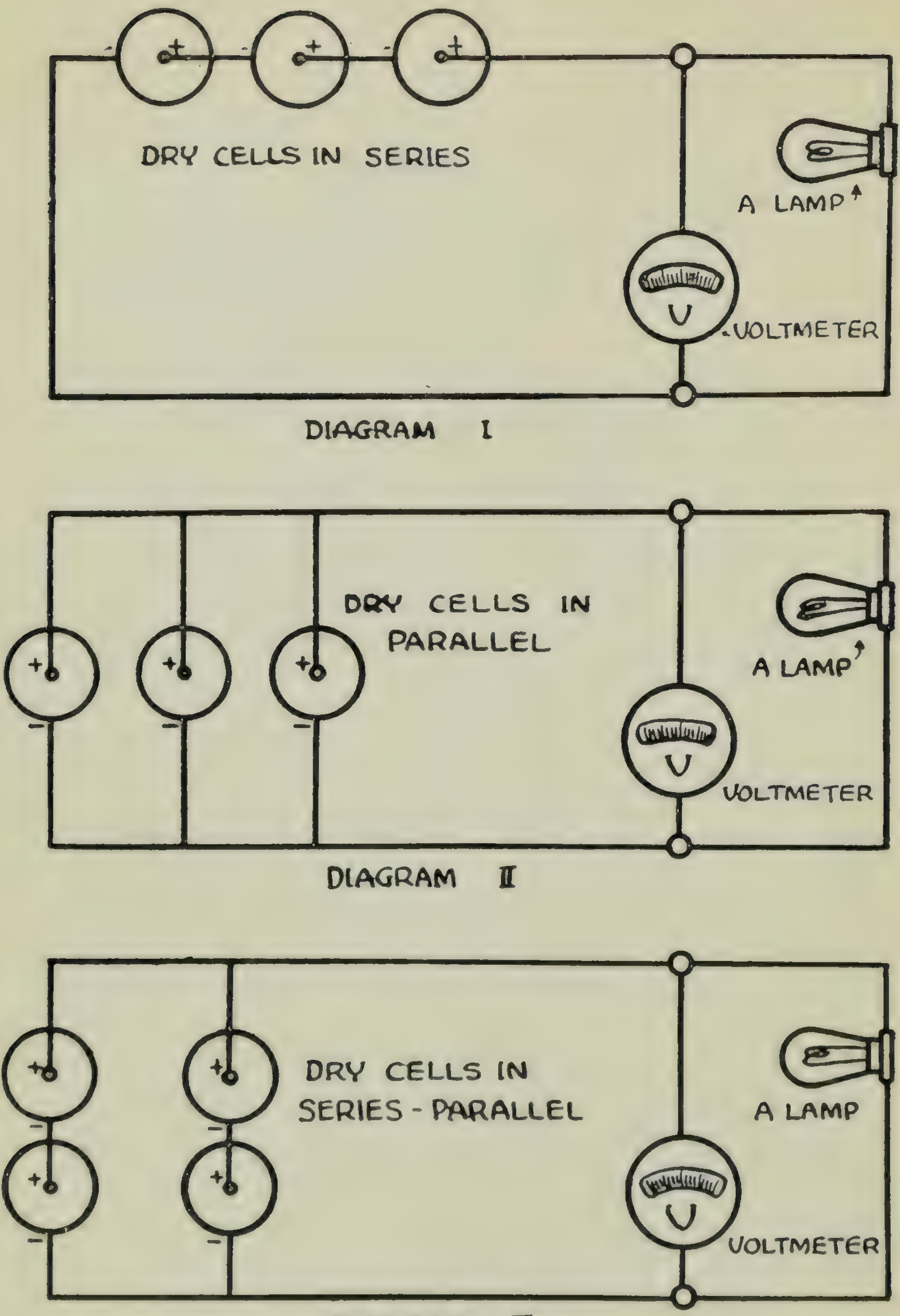


DIAGRAM I

DIAGRAM II

DIAGRAM III

Fig. VIII. Series and parallel connection of cells.

JOB VIII. SERIES AND PARALLEL CELLS.

Proposal. To connect three dry cells—

(a) In series,
(b) In parallel.

To study the effect in each case by connecting to a 6 volt lamp and a voltmeter.

Requirements. Three dry cells, one 6 volt lamp and receptacle, one pocket voltmeter having a range of 10 volts.

Procedure.

1. Measure the voltage of one cell by connecting the terminals to the voltmeter.
2. Connect the lamp to one cell and notice the result.
3. Connect three cells in series as shown in diagram (1) and repeat the above two tests.
4. Connect the three cells in parallel as shown in diagram (2) and test again.
5. Tabulate results as follows:

Cells	Voltage	Lamp—bright or dim
1 only		
3 in series		
3 in parallel		

6. Diagram (3) shows a series-parallel arrangement using 4 cells which may be tried.

LESSON.

As the voltage of one dry cell is 1½ volts, when three cells are connected in series, the total voltage is 4½ volts. This voltage is high enough to force current through the lamp and causes it to burn brightly. When the cells are connected in parallel, the voltage is 1½ volts, the same as one cell only. This is because each cell acts independently, and does not boost the voltage of the others as in the series connection. Hence we have the following rules:—

1. **Series cells.** When two or more cells are connected in series, the terminal voltage is the sum of the voltages of all the cells.
2. **Parallel cells.** When two or more cells are connected in parallel, the terminal voltage is the same as the voltage of one cell only.

QUESTIONS.

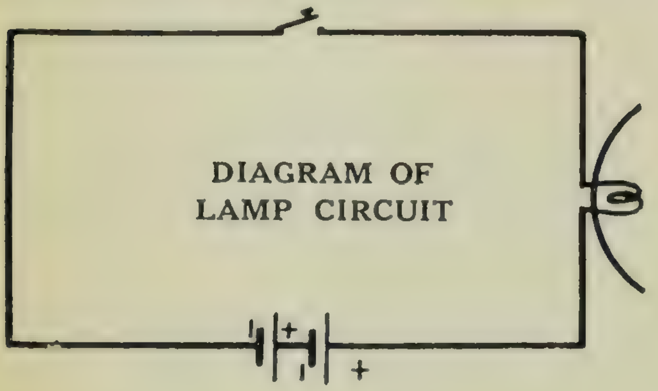
1. What is the voltage of 1 dry cell?
2. What is the voltage of 3 cells in series? of 7 cells ? of 100 cells?
3. Why did the lamp burn brighter when connected to 3 cells in series than with 1 cell only?
4. What is the terminal voltage of 3 cells connected in parallel? of 9 cells? of 60 cells?
5. What are the rules for finding the terminal voltage of series and parallel connected cells?

JOB IX. THE ELECTRIC FLASH LAMP.

Proposal. To dissemble and assemble an electric flash lamp and study its operation.

Procedure.

1. Remove base and dry cells.
2. Unscrew top cap and remove lens, reflector and lamp.
3. Examine all the details and study the path of the current through the cells, lamp and switch.
4. Make a sectional drawing of the lamp and a diagram of the circuit.



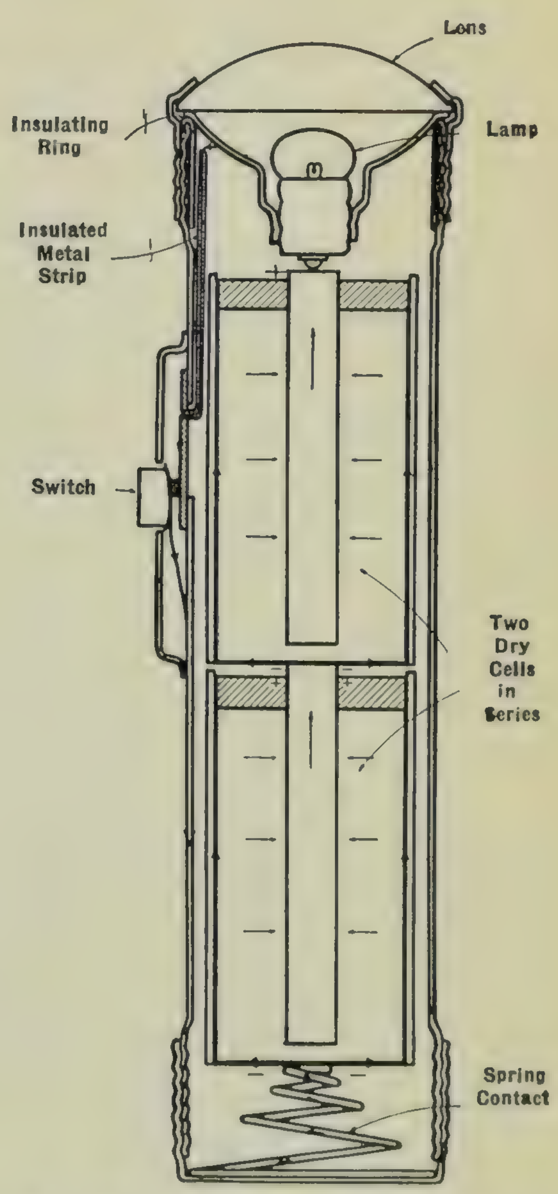


Fig. IX. The Electric Flash Lamp.

LESSON.

Electric flash lamps are made in many different sizes and types. The one shown in the figure is the most commonly used. There are no binding screws on the dry cells. The cells are connected in series by pressing the positive (carbon) terminal of the lower cell to the negative (zinc) shell at the bottom of the upper cell. The pressure is maintained by the spring at the bottom which also acts as a connector to the outside metal casing. The circuit is completed through the lamp switch. There are many different devices through which you may some day have to trace the circuit, and the flash lamp offers good practice in this work. The lens and reflector are designed to make the light project out in a straight beam so that all available light is concentrated on the object.

QUESTIONS.

1. What is the voltage rating of a lamp for a two cell flash lamp?
2. Name some other types and sizes of flash lamps.
3. Why are no binding-screw terminals used in a flash lamp?
4. In what way does the lens and reflector help to make the lamp more efficient?

JOB X. TESTING THE CONDITION OF DRY CELLS.

Proposal. To test old and new dry cells to determine their condition.
Requirements. One new dry cell and a few old ones, one pocket ammeter.

Procedure.

1. Test the new dry cell by connecting the ammeter to the terminals as shown in sketch. The following table may be used as a guide:

Ammeter Reading		Condition
Over 25 amperes		very good
20-25	,,	good
15-20	,,	fair
10-15	,,	poor
5-10	,,	very weak
under 5	,,	useless

2. Test the other cells and mark down for each the amperage and condition of the cell.

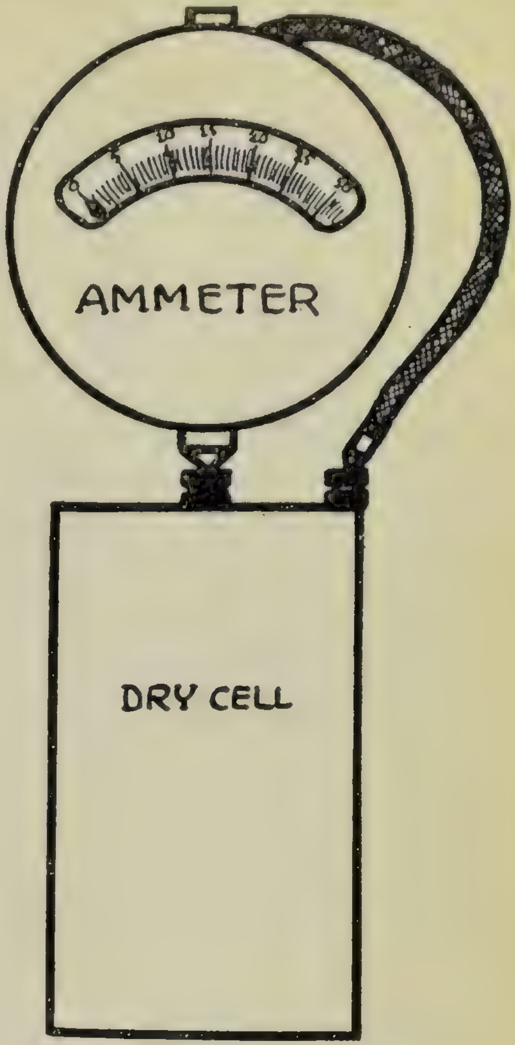


Fig. X. Testing Dry Cells.

LESSON.

Dry cells are composed of certain chemicals which combine when connected to a circuit and cause the current (amperes) to flow. In this way chemical energy is converted into electrical energy. As the chemicals become used up, the ability of the cell to deliver electric current weakens. An ammeter is an instrument which measures the current in amperes. By connecting the ammeter to the cell we can determine its condition. When you buy a dry cell you should have the salesman test it to make sure it is in good condition. If you are using dry cells for any purpose you should have a pocket ammeter to test them from time to time.

(NOTE: Forty-five volt radio batteries and storage batteries can **not** be tested in this manner.)

QUESTIONS.

1. What does an ammeter measure?
2. How can you tell when a dry cell is in good condition? fair condition? poor condition?
3. Why is it good practice to have a testing ammeter whenever dry cells are used?
4. Name three different places where you have seen dry cells used.

JOB XI. DRY CELL CONSTRUCTION.

Proposal. To examine the composition of a dry cell.

Requirements. An old dry cell which has been cut vertically through the centre.

Procedure. Examine the construction of the cell and make a sketch of the section from the cut cell, or copy the drawing shown in Fig. XI. Name each of the parts and the various materials on your drawing.

LESSON.

When coal or wood is burned, heat energy is produced. Burning is called combustion, which is a chemical reaction. An electric cell is composed of chemicals which, when connected to a circuit, produce an electric current. If a dry cell is cut with a hack saw through the middle, you see its construction. The outside shell is a cylindrical container made of zinc. This is lined with blotting paper soaked with sal ammoniac solution. The black powder is a mixture of ground carbon and manganese dioxide. In the centre is a carbon stick to which the positive terminal is attached. The top is sealed with pitch. In operation, the zinc acts as the fuel which is consumed by the sal ammoniac, producing electrical energy. Before the dry cell was invented, many forms of "wet" cells were used. In these cells the liquid solution was kept in jars and they were not easily carried about. Of these the Leclanche, Daniell and Edison-Lalonde were the most common. These are all known as "Primary" cells because they cannot be recharged. When used up, the chemicals were removed and new chemicals put in the jars.

QUESTIONS.

1. How is the sal ammoniac solution held in the cell?
2. What produces the electric current in the cell?
3. What is a "Primary" cell?
4. Make a sketch and name all the parts of the dry cell.
5. Name some other types of Primary cells.

DRY CELL CONSTRUCTION

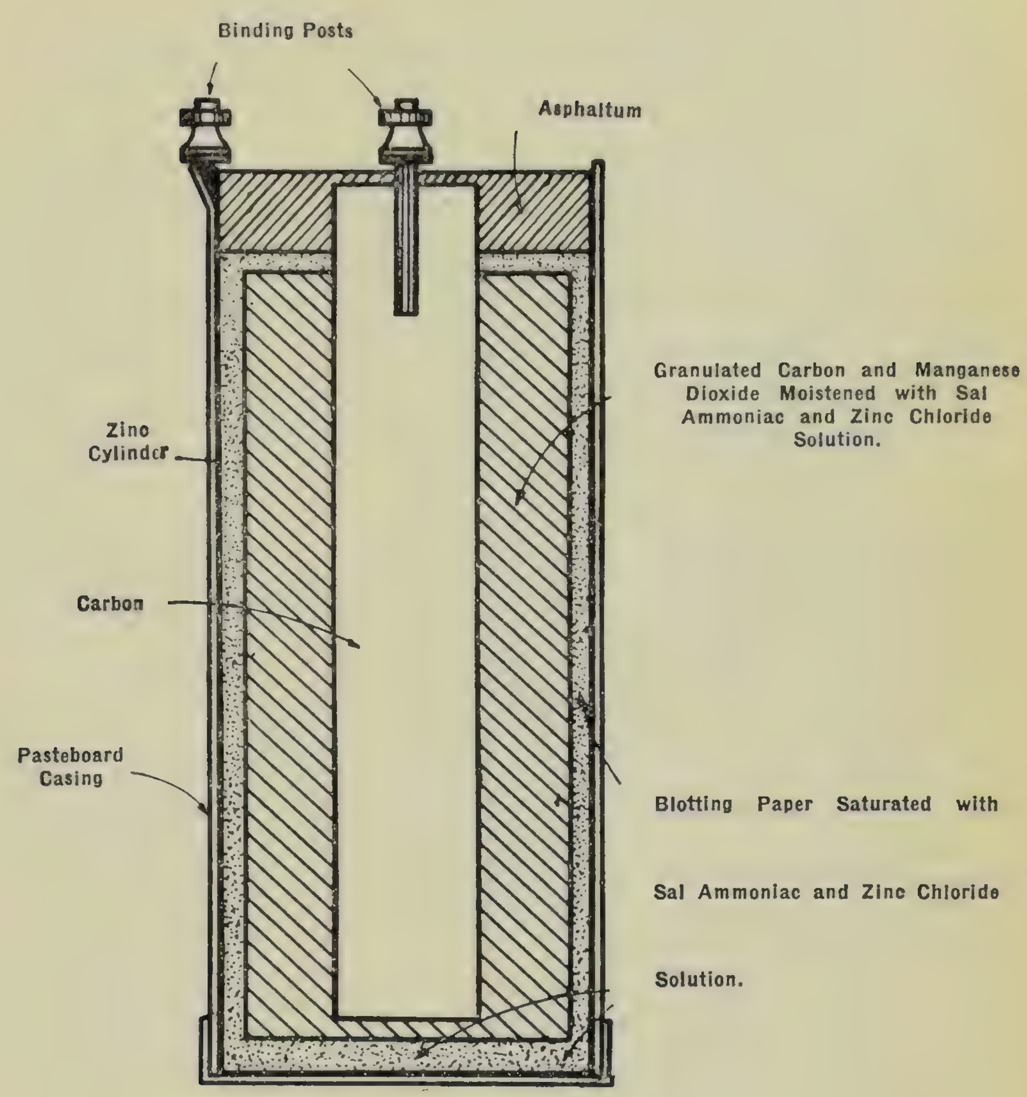

Binding Posts
Asphaltum
Granulated Carbon and Manganese Dioxide Moistened with Sal Ammoniac and Zinc Chloride Solution.
Zinc Cylinder
Carbon
Pasteboard Casing
Blotting Paper Saturated with Sal Ammoniac and Zinc Chloride Solution.

Fig. XI. Dry Cell Construction.

JOB XII. THE MAGNET.

Proposal. To study some properties of the magnet.

Requirements. A bar magnet, small pane of glass, small magnetic compass, sewing needle, small piece of the following metals: Iron, zinc, nickel, aluminum, brass.

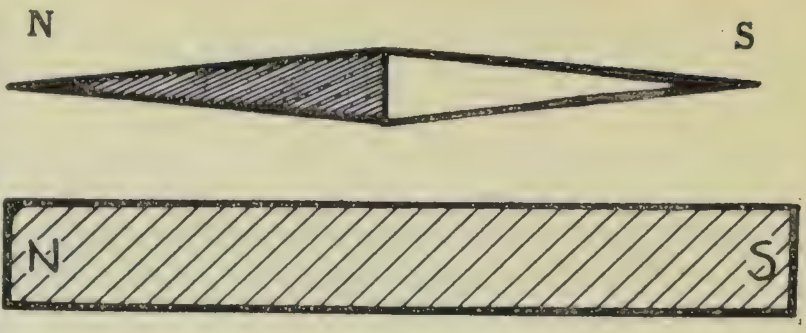


Fig. XII. Magnets.

Procedure.

1. Hold the bar magnet in one hand and touch the small piece of iron to each end. Does it attract the iron? Yes, it does. Now touch the magnet with the iron midway between the ends. Does it attract the iron here? No, very little, if at all. The greatest attraction we see is near the ends which are called the "poles" of the magnet.
2. Suspend the bar magnet by a fine silk thread. One end will swing towards the North Pole of the World. This is called the "north seeking" pole or North pole of the magnet. The other is called the South pole.
3. Place the small compass near the North pole of the magnet. It attracts the South pole of the compass needle. Now place the compass near the South pole of the bar magnet. It attracts the North pole of the compass needle.
   Rule. Unlike poles attract and like poles repel.
4. Place the glass between the magnet and the compass and repeat operation 3. The same effect is produced showing that the magnetism will pass through the glass. Magnetism can be made to pass through any substance, that is, it cannot be insulated.
5. Stroke the sewing needle or the blade of a pocket knife with the end of the bar magnet. Now notice that the needle or knife blade is magnetized.
6. Try and pick up different metals with the magnet. The iron and nickel only are attracted; cobalt is also magnetic. These are the only magnetic substances of any importance. Iron is the most important of all.
   Magnets are made of hard steel in two common forms, the "bar" and the "horseshoe."

QUESTIONS.

1. Where are the poles of a magnet located?
2. How is the North pole of the magnet determined?
3. State the rule of attraction and repulsion of magnetic poles.
4. Can magnetism be insulated?
5. What substances are attracted by a magnet?
6. What is the most important magnetic substance?
7. What are the common forms of magnets?
8. What are these magnets made of?

JOB XIII. MARINER'S COMPASS

Proposal. To make a Mariner's Compass.

Requirements. Two pieces of watch spring or steel needles about 1¼″ long, a piece of cardboard about 2″ square, a wooden plaque to serve as a base, as shown in sketch, a No. 00 dome fastener, a "soft" gramophone needle.

Procedure.

Cut a circle 1½″ in diameter from the cardboard. Punch a hole in the centre of card about ¹⁄₁₆″ in diameter. Glue the lower half of the dome fastener over the hole to act as a rest for the pivot. Drive gramophone needle through the bottom of the plaque at centre. Glue the two pieces of spring on the under side of the card and balance on pivot before drying. Magnetize the steel spring by stroking with a permanent magnet or by placing in a magnetizing coil. Using another compass draw, on a fixed paper, a line running North and South. Placing the centre line of the plaque over this drawn line, make a short mark to indicate N at the top of the plaque and also one on the mounted card at the same position. Remove card and carefully complete the drawing of the scale on the card. Replace card on pivot.

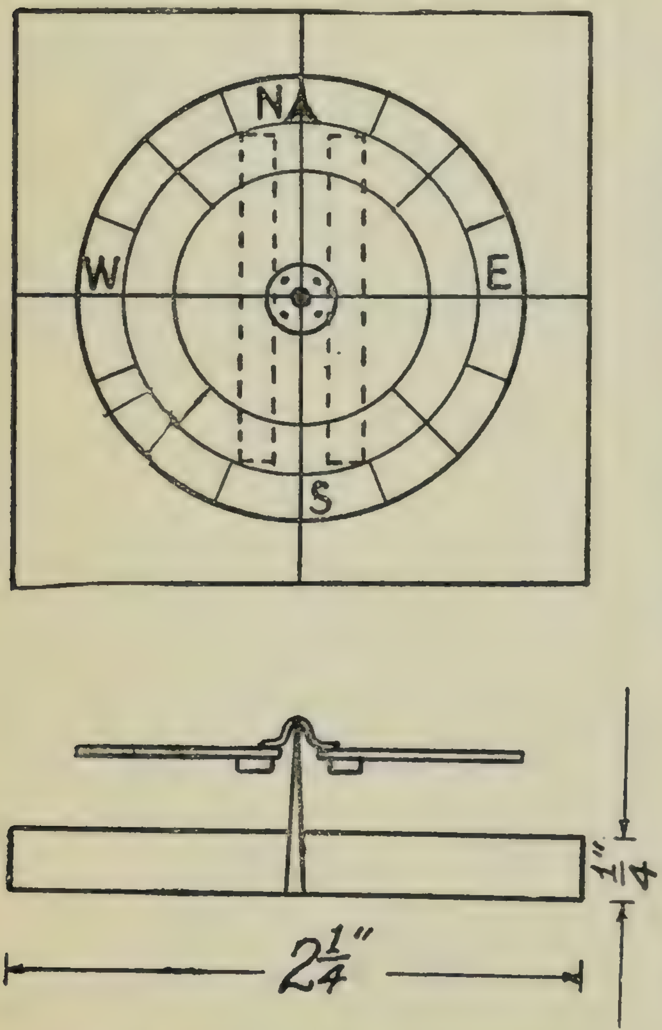


Fig. XIII. Mariners' Compass.

LESSON

A compass needle is influenced by the magnetism of the Earth which is a huge magnet. You will remember from your geography that the True North Pole is the point through which the axis of the Earth passes. The magnetic North Pole, however, is over 1,000 miles south of this at a point on the Arctic Coast almost directly north of Winnipeg. Hence the compass needle does not always point "True North" but to the "Magnetic North". Mariners always know this and make the necessary corrections when steering a ship on its course.

QUESTIONS.

1. Does the compass needle always point "True North"?
2. On what peninsula is the Magnetic North Pole? (Look it up on a map of Canada.)
3. Name three or four practical uses of a compass.

JOB XIV. MAGNETIC FIELD.

Proposal. To make a "picture" of the magnetic "field" about a magnet.

Requirements. A bar magnet, some iron fillings in salt shaker, and a piece of paper about 8″ x 10″, a small compass.

Procedure. Place the magnet on the table. Cover the magnet with the paper. Now sprinkle iron fillings over the paper and tap it gently until the "picture" appears.

NOTE: If **waxed** paper is used a permanent "picture" may be made as follows:—

Without disturbing the waxed paper warm it slightly by holding an electric heater over it (an electric toaster or small stove will do). The heat will melt the wax and allow the filings to stick to the paper. Remove the stove and your "picture" will set permanently. Now make a "picture" of the field about a horseshoe magnet. Place a compass in the field and notice how it points along the lines.

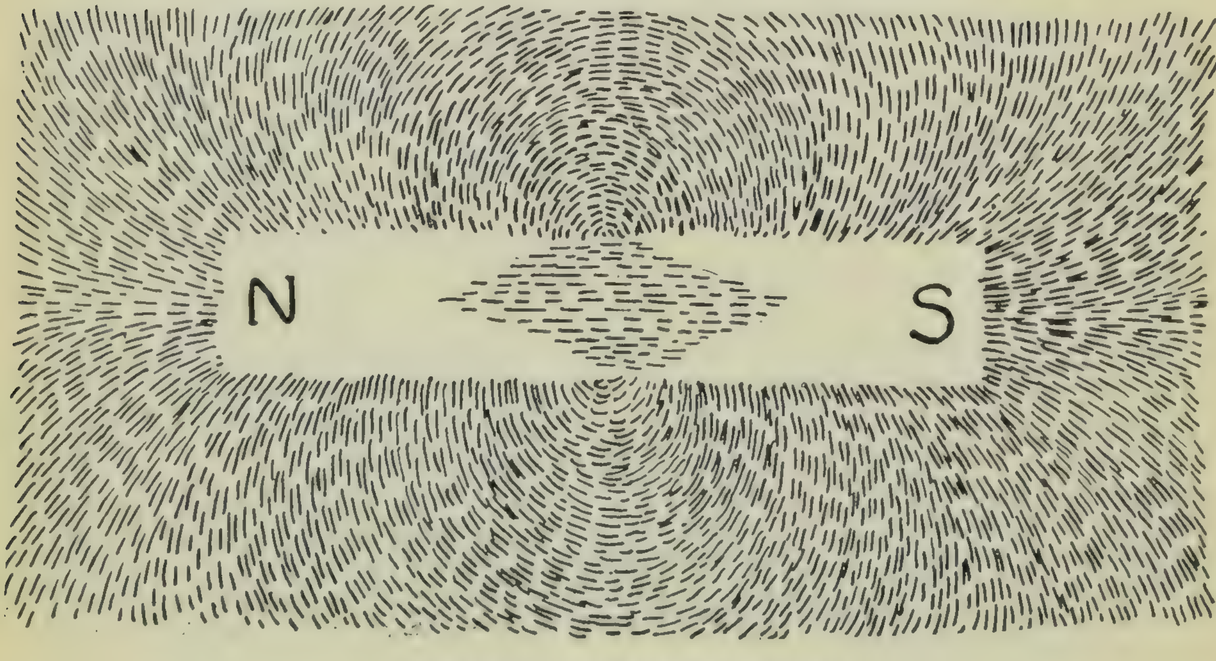


Fig. XIV. The Magnetic Field.

LESSON.

The magnetic "field" about a magnet is the space surrounding a magnet over which it has a magnetic influence. The "picture" shows paths of the magnetic lines of force. The compass indicates the direction of these lines. They run from the North pole to the South pole outside the magnet. Magnetism is different from gravity because gravity attracts everything whereas magnetism attracts only iron, nickel and cobalt. We shall see later that magnetism and electricity are very closely related.

QUESTIONS.

1. What is the "field" of a magnet?
2. What is the direction of the "lines of force?"
3. How does magnetic attraction compare with the attraction of gravity?
4. Where do the lines of force seem to concentrate?
5. What other materials are magnetic besides iron?

JOB XV. THE ELECTROMAGNET.

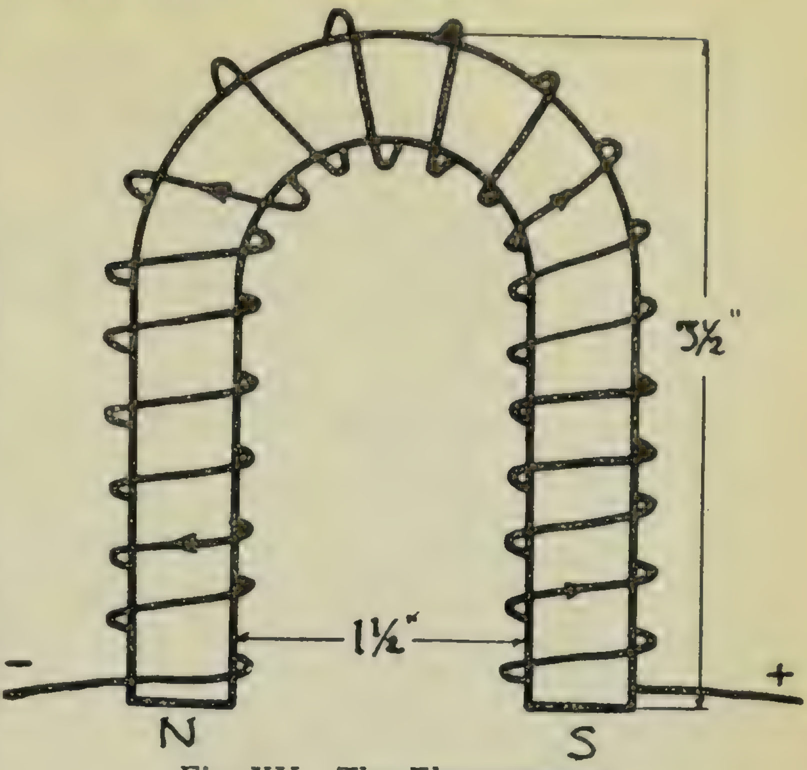


Fig. XV. The Electromagnet.

Proposal.

To make an electromagnet.

Requirements.

One 8″ piece common ¼″ round iron bent to form a horseshoe; 10 to 15 feet of No. 28 D.c.c. magnet wire, a dry cell and a magnetic compass.

Procedure.

Wind the wire onto the soft iron core, leaving about six inches of wire at each end. Connect the ends of the wire to the dry cell. Now test whether it will pick up any small pieces of iron (tacks, etc.) Test with a magnetic compass and mark the North pole of the magnet. Reverse the current through the magnet and test again. Notice the polarity now. Is the North pole the same as before? (Do not leave the magnet connected too long, as it will drain the dry cell). Disconnect and see if it will pull up tacks or iron now.

LESSON.

Electric currents produce magnetism. This magnetism will pass through the insulation of the wire into the iron core. The iron is thus converted into a magnet which behaves the same as a permanent horseshoe magnet. However, the magnetism exists only as long as the current is flowing. When the current stops, the iron core retains very little magnetism. Further, the polarity of the magnet depends upon the direction of the current. There is a rule for this called **the Right Hand Rule**—Grasp one coil of the magnet by the right hand with the fingers pointing in the direction of the current, the thumb will now be pointing to the North Pole.

Magnets are wound with magnet wire. This is simply copper wire wound with thin insulation. "D.c.c." means double cotton covered; "S.c.c." single cotton covered; "D.s.c." double silk covered. Magnets may be made stronger by winding more turns on the core or increasing the electric current.

QUESTIONS.

1. What produced the magnetism in the iron core of the electromagnet?
2. Did the electric current pass through the iron core?
3. What happened when the current was reversed?
4. Give two reasons to show electricity and magnetism are different.
5. What is D.c.c. wire? S.c.c. wire? D.s.c. wire?
6. In what ways may an electromagnet be made stronger?

JOB XVI. MAGNETIZING AND DEMAGNETIZING COIL.

Proposal. To magnetize and demagnetize a pocket knife.

Requirements. A magnetizing coil, a 6-volt storage battery, and a bank of three lamps in parallel.

NOTE: The coil may be made by winding 400 feet (5 lbs.) of No. 14 D.c.c. wire on a wooden form as shown in the sketch; this should give about one ohm resistance.

Procedure.

1. Test your knife in some iron filings and notice whether or not it is already magnetized.
2. Connect coil to battery and place knife inside the coil.
3. Disconnect coil and test the knife with iron filings, also present knife to a magnetic compass and notice which end is the North Pole and which is the South Pole.
4. Now connect lamp bank in series with the coil. (Have instructor check your connections.) Plug into 110V. A.C. convenience outlet; now pass your knife slowly through the coil. You will now find the magnetism has disappeared.

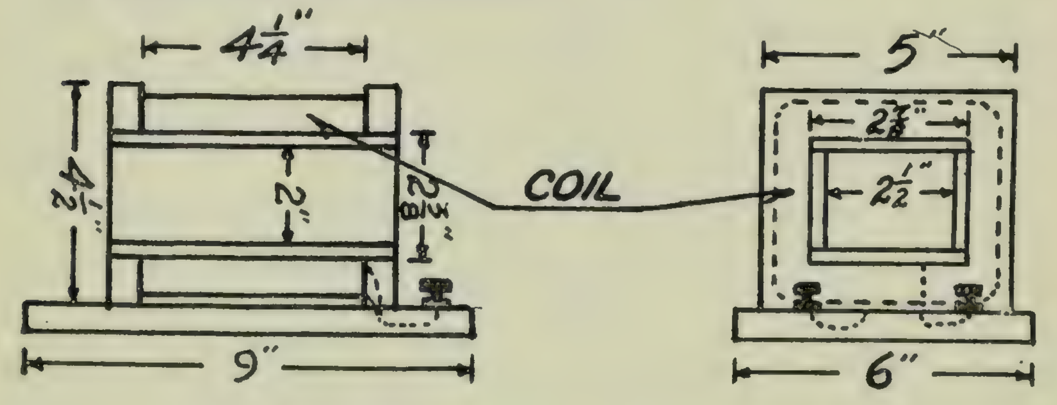


Fig. XVI. Magnetizing and Demagnetizing Coil

LESSON.

You have seen in Lesson XV. that an electric current produces magnetism in a soft iron core. Your knife is made of hand steel and retains its magnetism while the soft iron does not. The battery delivers "Direct Current", that is, it is always in the same direction. The "Alternating Current" from the convenience outlet is reversing to and fro very quickly, and as you pass your knife through the coil this reversing action removes the magnetism and causes the demagnetizing effect.

QUESTIONS.

1. What produced the magnetism in your knife?
2. Why does your knife retain its magnetism?
3. What is the difference between "Direct" and "Alternating" Current?
4. How did the alternating current demagnetize your knife?

JOB XVII. THE ELECTRIC BELL.

Proposal. To make a detailed sketch of the electric bell and to study its operation.

Requirements. An electric bell, a dry cell, some wire.

Procedure. Remove the cover of the bell and examine all the parts. Connect it to the dry cell and observe how it operates. Make a very careful detailed sketch of the bell and show by arrows the path of the current from one terminal through the coils to the other terminal.

Now study out and explain how the bell operates.

LESSON.

In tracing out a circuit through any electrical device, start at one terminal and follow the path of the current. Most bells and many other devices use the iron frame as a "ground" return, meaning that the current returns through some material that is not insulated. Study this in the bell you are examining. The grounded side is generally connected to the negative terminal of the battery.

The electromagnet is a very important electrical device. Most electrical appliances are operated by this means. Annunciators, telegraph instruments, telephones, etc., are all dependent upon the electromagnet.

QUESTIONS.

1. In the electric bell what pulls the hammer toward the bell?
2. What pulls the hammer away from the bell?
3. Why is the electromagnet a very important device?
4. Name some other electrical appliances that are operated by the electromagnet.
5. Name some electrical appliances that are not operated by the electromagnet.
6. Make a detailed sketch of the electric bell and explain its operation.

JOB XVIII. THE ANNUNCIATOR.

Proposal. To wire up and operate a small annunciator.

Requirements. A small annunciator (four station), bell, four push buttons, three dry cells, wire.

Procedure. Set up annunciator in operating position. A vertical wiring board is best for this job because most annunciators operate in a vertical position. Place bell, push buttons and cells in position. Now wire up, remembering the wiring rules and studying the sketch. Keep your work neat. Wires may be held in position with cleats or staples.

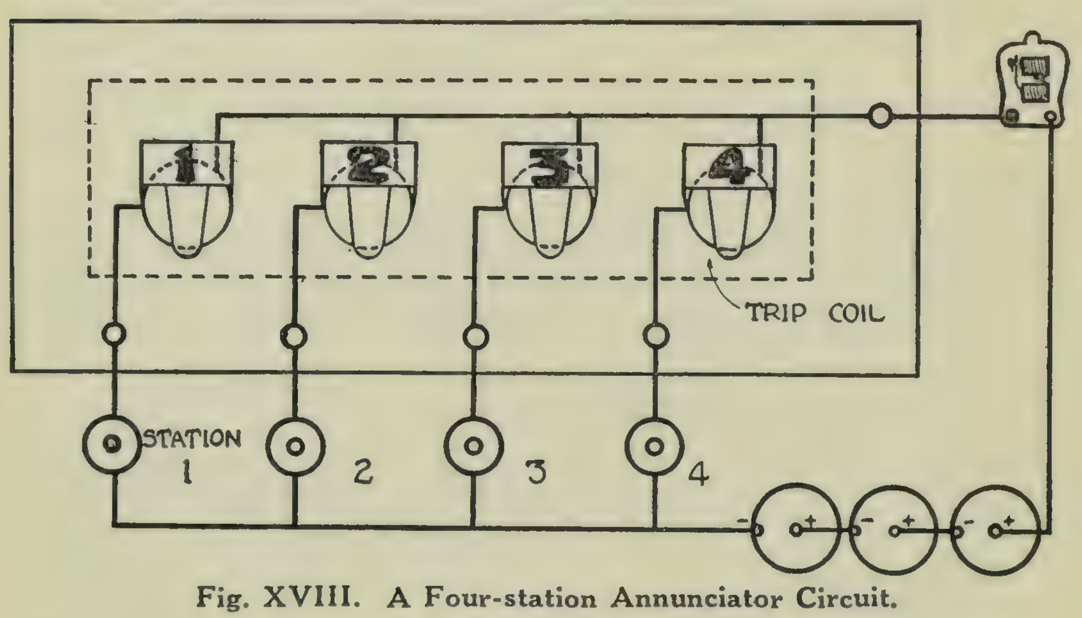


Fig. XVIII. A Four-station Annunciator Circuit.

LESSON.

The annunciator is operated by a small electromagnet. This attracts a small armature or trigger which releases the catch and lets the indicator drop. The indicator is reset by a little handle which pushes it up under the catch again. The bell or buzzer is placed in series with the annunciator to give an audible signal when any push button is pressed. Annunciators are used in hotels, sleeping cars, elevators, etc. Large annunciators are built for over one hundred stations but they are all operated in the same manner as a small one. There are as many circuits in the system as there are indicators. They have all a common return wire to the battery.

QUESTIONS.

1. How is the indicator of the annunciator operated?
2. How is the annunciator reset?
3. Where are annunciators used?
4. How many stations may be operated on one annunciator system?
5. How many circuits are there in a four-station annunciator?

JOB XIX. THE MOTOR.

Proposal.

To connect up a toy motor and name the parts.

Requirements.

Small toy motor (a "Meccano" or "Erector" or "St. Louis" motor will do), three dry cells, some bell wire.

Procedure.

1. Examine motor carefully.
2. Study the various parts by referring to sketch.

Connect one cell to motor — two cells in series — then three cells in series.

4. Make a sketch of your motor, using the figure as a guide and name the parts.

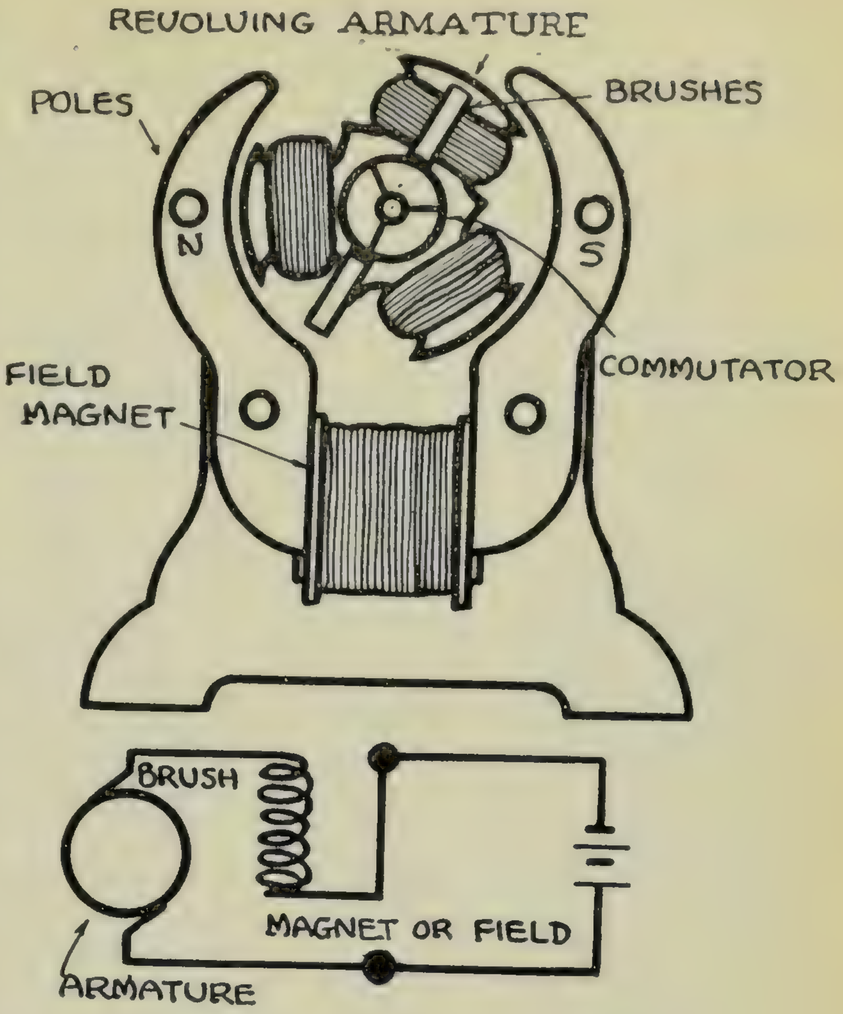


Fig. XIX. A Small Electric Motor.

LESSON.

The electric motor is composed of two electromagnets, the stationary "field magnet" and the revolving magnet called the "Armature". There is a magnetic pull between these two which causes the armature to rotate. The electric current enters and leaves the armature by the "brushes" which ride on the commutator. The commutator is made of "segments" of copper which guide the current in the proper direction so as to keep up the rotation. There are a great many different kinds of motors but they all depend on the magnetism produced by the current to make them turn around. In most small motors the more voltage that is applied, the faster they turn. One must be careful, however, not to have the voltage too high or it will damage the motor. The proper voltage is generally stamped on the outside.

QUESTIONS.

1. How does the current get into the armature of the motor?
2. How many volts were applied when you used three dry cells in series? Two cells?
3. What effect does increasing the voltage have on the operation of the motor?
4. What makes the armature turn around?

JOB XX. EXTENSION CORD.

Proposal. To assemble an extension cord for a lamp.

Requirements. One lamp socket, one separable plug, 7 feet of lamp cord.

Procedure. Take the socket apart and also the plug. Notice how carefully each is made. Name all the parts and check up according to the sketch. Learn to make the Underwriters' Knot. Using a knife, carefully bare at the ends about one inch of the copper wire strands. Do not cut any of them. Pass the wire around a blade, and screw down tightly under binding post. Now attach the other end of the wire to the socket. Slip the cap on the cord first. Tie the underwriters' knot and then, having left about an inch or so of wire, screw the ends down under the binding posts. Assemble the socket and test out with a lamp.

LESSON.

Let us examine the assembled extension cord. First look at the lamp socket and notice how carefully it is made. The shell and cap are lined with insulating paper to protect anyone from getting a shock. The key has a pointer on it. When it points towards the lamp the switch is "on" but when turned away from the lamp it is "off". The black fibre bushing prevents the wire covering and insulation from being cut by constant movement. The cap is threaded to fit ⅛″ pipe. This is done so that, if necessary, the bushing may be taken out and the socket screwed to a table lamp or other fixture. There is a little set screw provided to prevent the socket from becoming unscrewed from the fixture to which it may be attached. The underwriters' knot is tied so as to take the strain off the binding screws when the wire is pulled.

Now notice the separable plug. The screw section may be removed so that the plug may be inserted into any convenient outlet. The knot may be used here, but more generally each wire is just passed around a blade and under the binding screw. This makes a sort of half-hitch on the blade and relieves the strain on the binding screws.

Extension cords must never be hung over nails nor fastened to the walls in any way. They must be quite free from end to end. No splice is allowed in the cord because it might come apart and cause an electric flash. It is very dangerous to tack lamp cord along the base boards, picture moulding, or around doors and windows. Many fires have been caused in this way.

QUESTIONS.

1. Why is the underwriters' knot used?
2. What is the purpose of the fibre bushing in the socket?
3. Why is the cap threaded to ⅛″ pipe size?
4. What is the set screw in the cap for?
5. In the plug, why pass the wire around the blade before fastening?
6. Why should extension cords of any kind never be spliced?
7. Why should extension cords never be hung on nails or tacked to the walls?

EXTENSION CORD

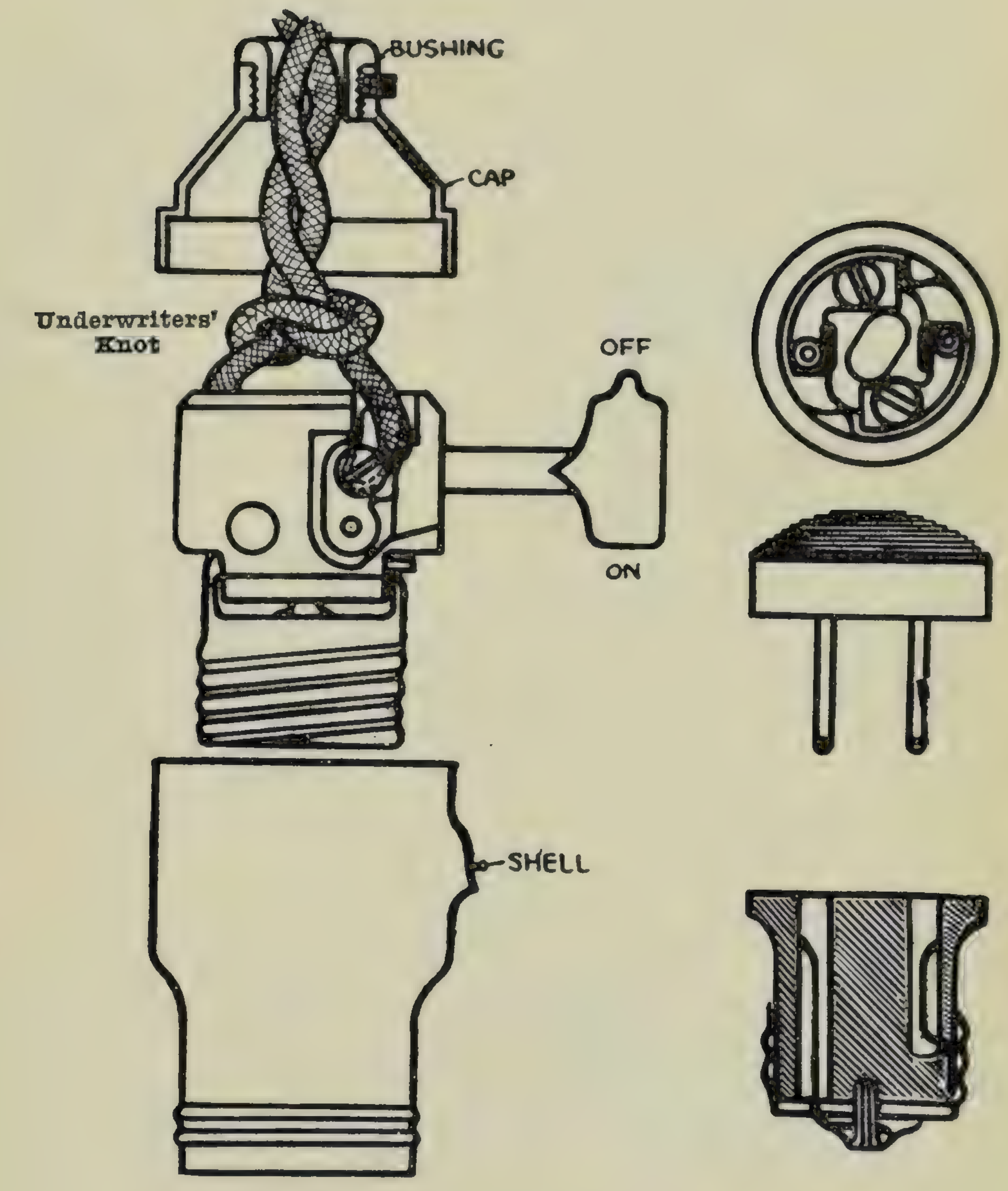


Fig. XX. Extension Cord.

JOB XXI. HEATER CORD.

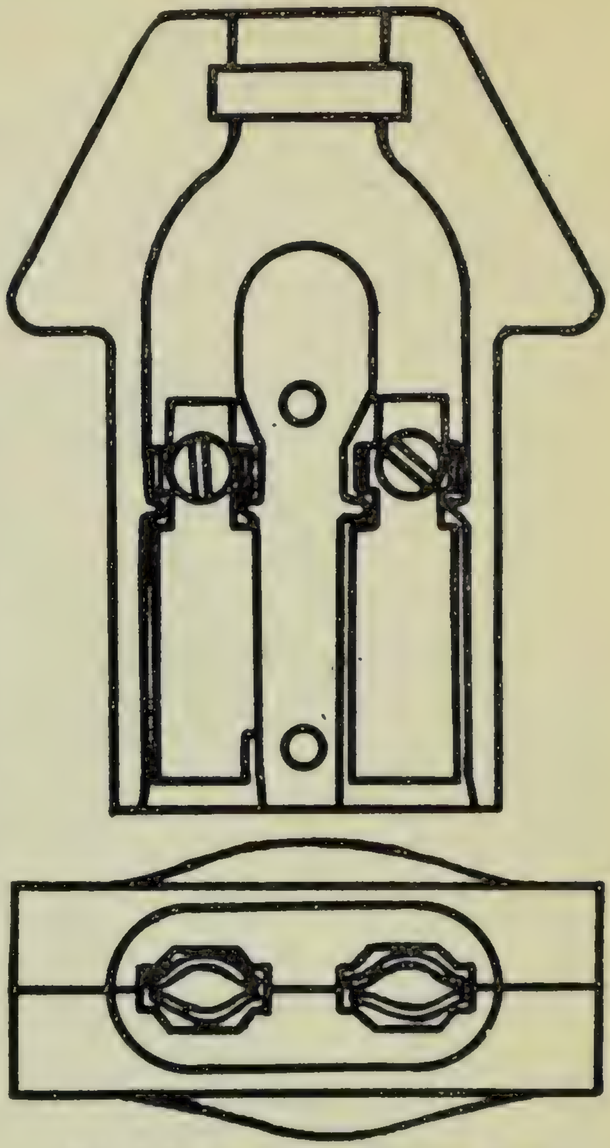


Fig. XXI. Iron Plug (Heater Cord).

Proposal.

To assemble an electric heater cord.

Requirements.

Heater cord, one heater plug, one separable plug.

Procedure.

Take both plugs apart and examine carefully. Prepare ends of the cord by removing about 1½″ of insulation. Be careful not to cut the fine copper wire of the cord. Count the number of strands and compare with the number in the ordinary lamp cord. Now screw the ends down under the binding posts of the heater plug and assemble the parts. Connect separable plug as in Lesson XX. Test out.

LESSON.

Heater cords differ from lamp cords in many respects. This is because they have a much heavier duty to perform. Electric flat-irons, for instance, take ten times the electric current of the ordinary lamp. For this reason they are made of much heavier wire. You will discover this if you count the strands in each. The insulation is also different. There is first a rubber cover, then an asbestos braid and on top of this a heavy cotton braid. This is because the cord is subject to constant working to and fro, giving it much more wear. Even then it wears through after using for some time. The break generally takes place at the iron plug. Most iron plugs are provided with a wire spring through which the cord passes. This saves much wear and the cord lasts longer.

QUESTIONS.

1. In what way does the wire in a heater cord differ from that in a lamp cord?
2. Why is this necessary?
3. In what way does the insulation of the heater cord differ from the lamp cord?

JOB XXII. FIRE ALARM CIRCUIT.

Proposal. To connect up a Fire Alarm Circuit so that by operating any one of the Fire Alarm switches all the fire gongs will ring.

Requirements. Three fire gongs, three fire alarm switches, one battery of dry cells or storage battery, wire.

NOTE: Ordinary bells and push buttons may be used for practice.

Procedure.

1. Arrange materials on wiring board and screw into place.
2. Wire up neatly according to diagram. Rat tail splices may be used at all joints.
3. Test out.

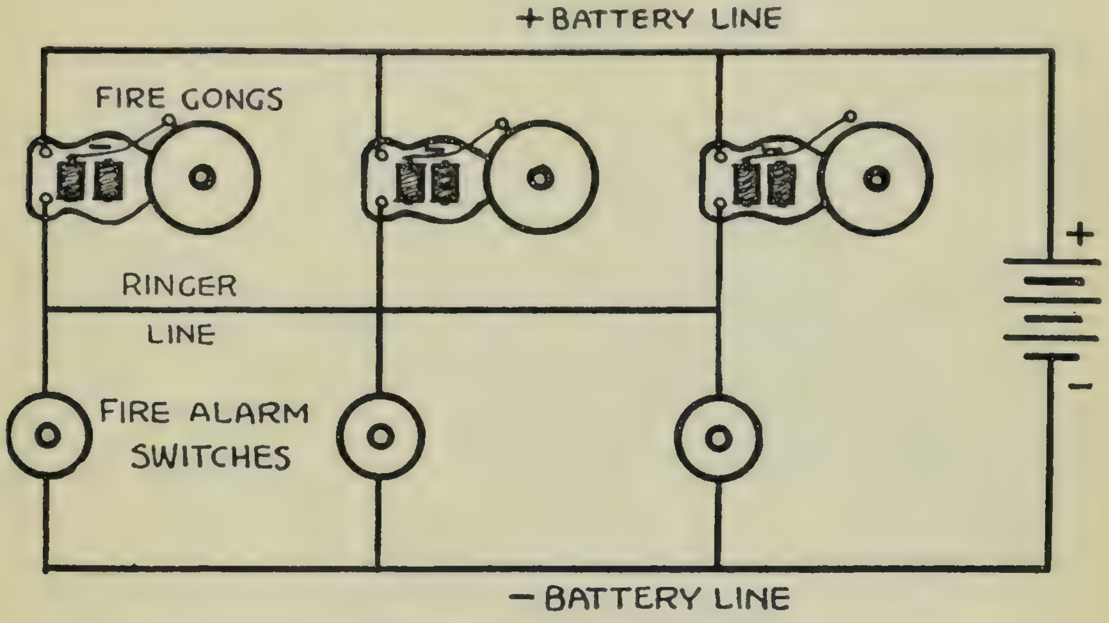


Fig. XXII. Fire Alarm Circuit.

LESSON.

Fire gongs should be operated by a battery of dry cells and installed independent of any other electric wiring in the building. The whole battery should be renewed every year because dry cells deteriorate in time, even if not used. The gongs should be tested at least once a month to make sure they are in good working order. This is another circuit in which the Wiring Rules apply.

QUESTIONS.

1. Why should fire gongs be operated independently by dry cells?
2. Why should the dry cells be renewed yearly?
3. How often should the gongs be tested?
4. In case of fire in an apartment house, what might happen if the fire gongs failed to operate?

JOB XXIII. RETURN CALL CIRCUIT.

Proposal. To connect up a Return Call Circuit in which a signal from "A" will call "B" and also a signal from "B" will call "A". This circuit uses only 3 wires between stations.

Requirements. Two push buttons, two bells, one dry cell, wire.

Procedure.

1. Set up a bell and push button at position "A" and also at position "B". Screw them into place. Wire up according to the diagram. Test out the circuit.
2. Draw a diagram of a circuit to operate in the same manner but using the three wiring rules. Wire up this circuit also.
3. Repeat the first part using a "grounded" return.

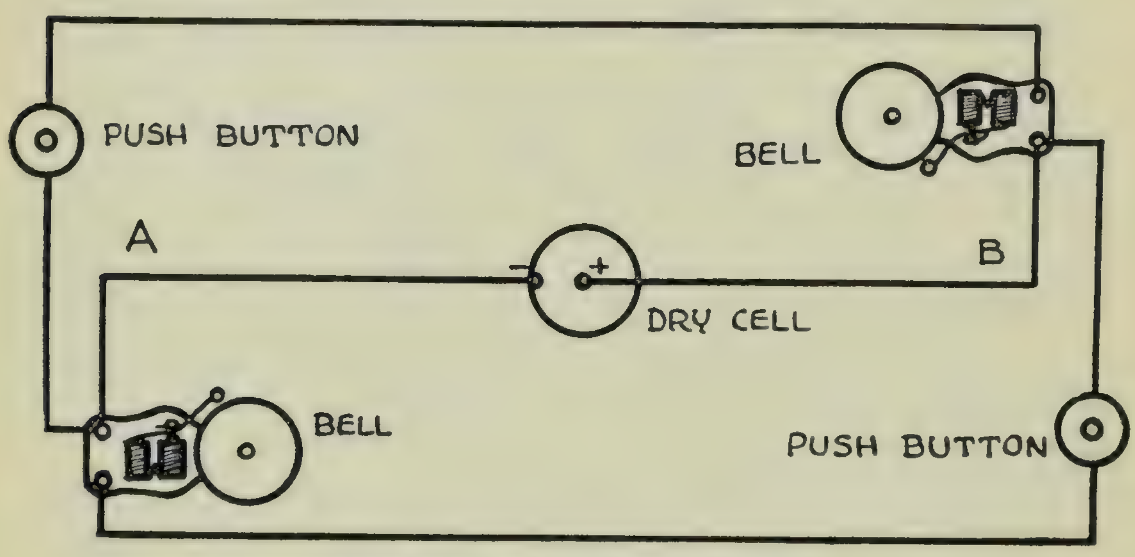


Fig. XXIII. Return Call Circuit.

LESSON.

This circuit is frequently used between an office man and his stenographer where return signals are required. He may signal to her when she is wanted or she may signal to him to answer the telephone. It is also interesting because the Wiring Rules do not apply. There are only three wires between stations which may be reduced to two by using a water pipe as a "ground" return. If the Wiring Rules are applied, a circuit may be drawn in which four wires are required to be run between stations. This is not so economical or necessary.

QUESTIONS.

1. Where might this circuit be used?
2. What is meant by a "grounded" return?
3. Make a sketch showing how this circuit could be completed by the application of the three wiring rules.

JOB XXIV. THE ELECTRIC DOOR LATCH OPENER.

Proposal. To connect up and operate an electric latch opener.

Requirements. A night latch and electric door latch opener mounted as shown in sketch, three dry cells and a push-button.

Procedure. Connect the two cells and push-button in series with the door latch opener. Remove the cover of the opener if possible, and examine its operation. You will notice an electromagnet which pulls away the "catch" and so allows the bolt to pass. There are several different makes of this device, but they all operate on very much the same principle.

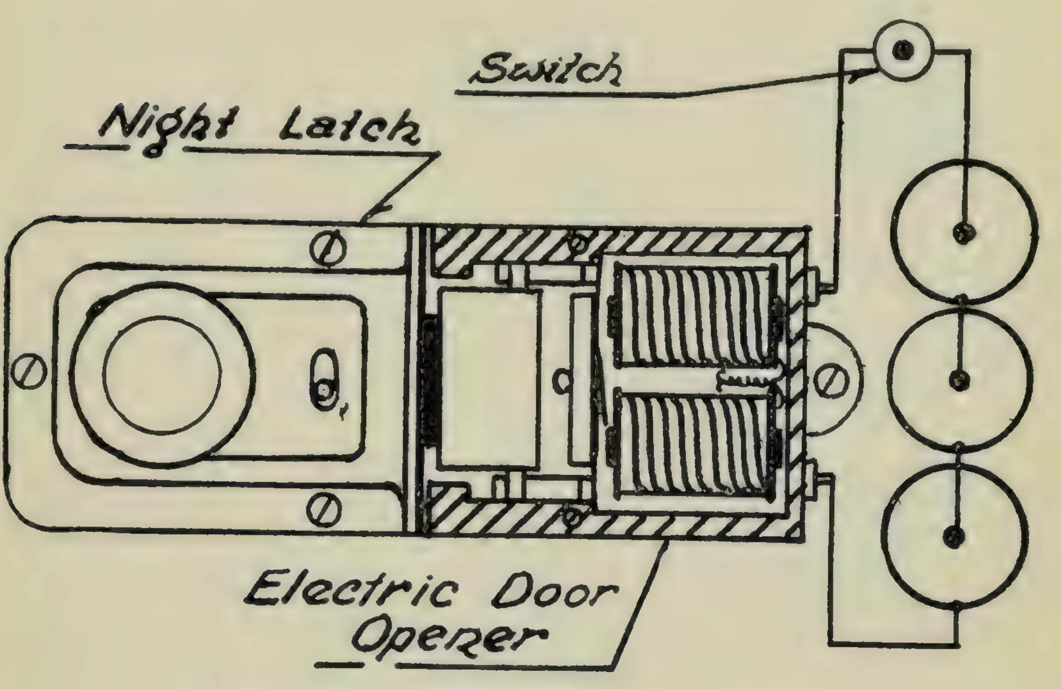


Fig. XXIV. Electric Door Latch Opener.

LESSON.

The electric door latch opener is another device operated by an electromagnet. You will notice the similarity between the operation of this and the annunciator drop indicator. They both operate a release catch by an electromagnet. This one is of a heavier construction, however. This device is especially convenient for opening from the landing above, a front door which is at the bottom of a staircase. It saves running up and down the stairs. It may be used in office doors operated from a desk, etc.

QUESTIONS.

1. What is the electrical principle of the electric door latch opener?
2. What is the advantage of such a device?
3. Make a sketch of the inside detail of the opener.

JOB XXV. AUTO LIGHTING (Head and Parking Lights).

Proposal. To construct an automobile lighting circuit containing two head lamps and two parking lamps.

Requirements. Four 6 volt lamps, four miniature receptacles, one 6 volt storage battery, one three-point switch.

Procedure. Set the receptacles and switch on the wiring board in similar positions as in the diagram. Screw these firmly into place. Now wire up according to diagram and test out by connecting to battery.

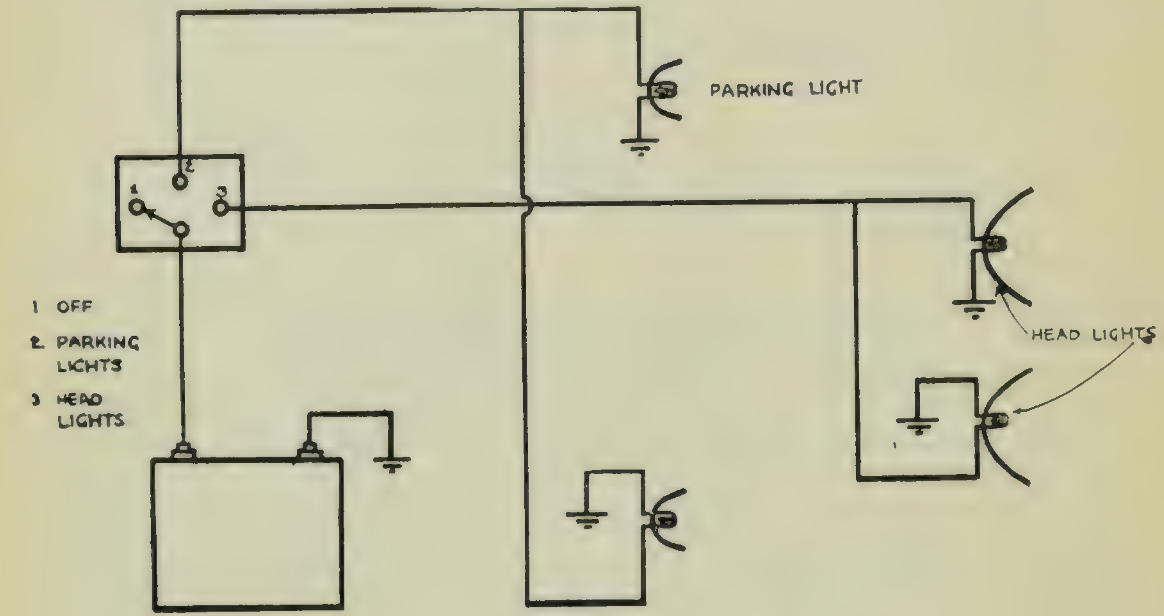


Fig. XXV. Auto Lighting (Head and Parking Lights).

LESSON.

This is a lesson in switching. The switch has three positions, "Off", "Parking", and "Head". By turning the switch any one of these desired conditions may be obtained. To assist in wiring it is well to apply the Wiring Rules. These should be slightly changed to fit the situation as follows:—

1. Connect one side of the battery to all lamps through "ground."
2. Connect the other side of the battery to the switch arm.
3. Connect each switch point to the lamps it is intended to operate.

The tail light should also be connected to this circuit so that it lights when either head or parking lights are used. If time permits it might be well to draw a diagram including this light and connect it up on the board. (Add another switch point at 2 and 3.)

QUESTIONS.

1. What is the object of having head and parking lights?
2. What is the purpose of the three-point switch?
3. State the wiring rules as applied to this circuit.
4. Draw a diagram of an auto lighting system having head and parking lights, and also the tail light.

JOB XXVI. AUTO LIGHTING WITH "DIMMER".

Purpose. To connect two head lights operated through a three-point switch with dimming resistance.

Requirements. Two 6 volt lamps, two miniature receptacles, one 6 volt storage battery, one three-point dimmer switch.

Procedure. Set the receptacles and switch on the wiring board in similar positions as in the diagram. Screw this firmly in place. Now wire up according to the diagram and test out by connecting to battery. NOTE: The grounded points must all be connected together.

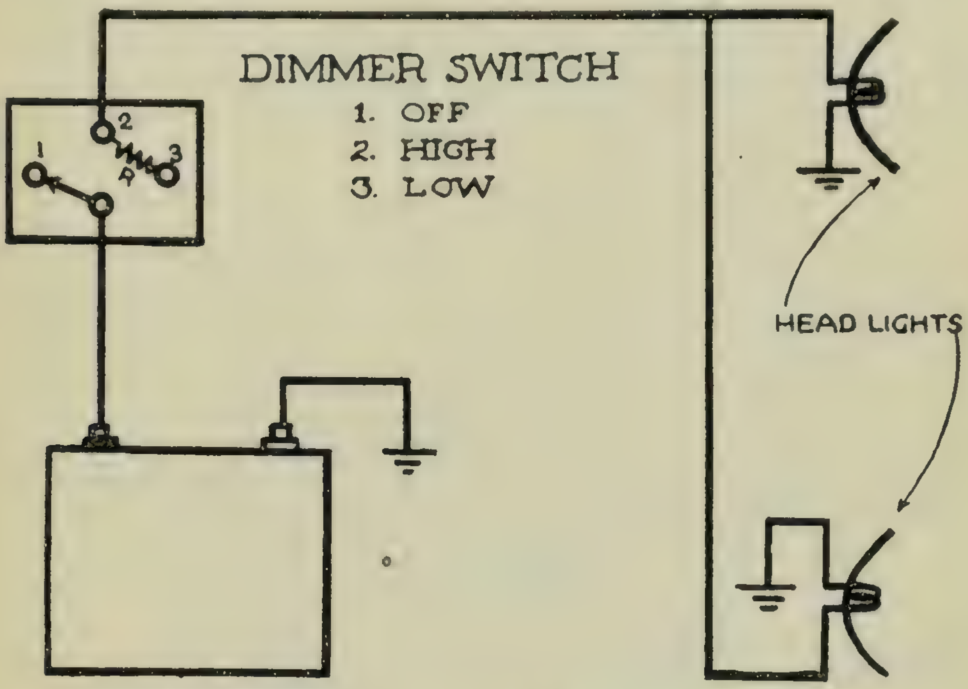


Fig. XXVI. Auto Lighting with "Dimmers".

LESSON.

This system has become obsolete for auto lighting, but it affords an interesting example of the **resistance** effect. A **resistance** is simply a wire of certain material which retards the flow of electric current. When it is placed in series with the lamps, the current is thereby reduced and the lamps do not burn so brightly, having a corresponding dimming effect. This system is also used in theatres where large and expensive dimmers are installed. These are large variable resistances called rheostats which are placed in series with the lamps, and the operator can gradually turn the lights to any degree of illumination desired.

QUESTIONS.

1. Why is it necessary to have a dimmer on bright head lights?
2. How is the dimming effect produced?
3. What is a resistance?
4. In what other places are dimmers used?
5. What is a rheostat?

JOB XXVII. ELECTROPLATING.

Proposal. To deposit a coating of copper on an iron strip.

Requirements. A glass tumbler, a strip of copper and a strip of iron (or brass or another strip of copper), a solution of copper sulphate, sandpaper or steel wool and two dry cells.

Procedure. Clean iron strip with sandpaper to remove all dirt and grease. Place solution of copper sulphate in the glass tumbler and then insert copper and iron strips into the solution. Connect wires to the strips. They may be soldered on or attached by bending over the ends of the strips and squeezing the wire in the lap. Connect to the dry cells which must be in series. Be sure you connect the copper to the positive terminal and the iron to the negative terminal. Allow the current to flow for about ten minutes. You will now find the copper has been deposited on the iron strip.

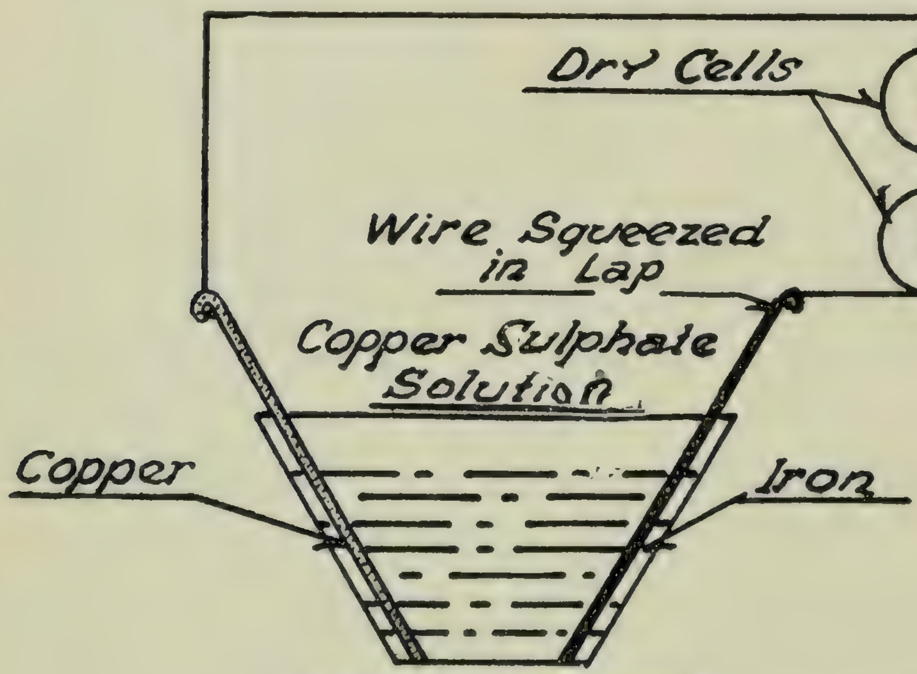


Fig. XXVII. Electroplating.

LESSON.

Electroplating is a process of depositing metal on an object from a solution by an electric current. The metal is carried over by the current in the same direction as the flow. Nickel, silver, gold and other metals are plated on in this manner from solutions of metallic salts. Many large industries use this method instead of dipping the objects in the molten metal which is an old way of plating.

QUESTIONS.

1. Why must the iron strip be cleaned with sandpaper?
2. Which way must the current flow?
3. What other metals may be plated in this manner?
4. Why is this a very important process?
5. What is this process called?

JOB XXVIII. TO MAKE A SIMPLE STORAGE CELL.

Proposal. Make a simple storage cell and charge it.

Requirements. Two pieces sheet lead about 2″ x 3″, one block of wood 1″ x 1″ x 3″, two one-half inch screws, one small glass jar about three-quarters full of dilute sulphuric acid, one large storage battery, ammeter, rheostat, wire, bell or buzzer.

Procedure. To make the simple storage cell, fasten strips of lead to wooden block, placing two short pieces of bell wire under the screws. Place these in the sulphuric acid solution with the wood resting on the edge of the jar. Connect to large storage battery through ammeter and rheostat as shown in sketch. Regulate current to about one ampere and charge for fifteen minutes.

In charging all batteries, connect positive of battery to positive of charger. Disconnect charger and connect simple cell to bell or buzzer and test how long it will ring.

LESSON.

The chemical reactions in a storage battery are beyond the scope of this book. However, it must be understood that when the charging current is passed through, a chemical change takes place on plates and in the liquid. This liquid is called the electrolyte and is a solution of sulphuric acid. One must not think that the cell is filled with electricity as a balloon is filled with air. The electric current passes right through the cell and in so doing converts the electrical energy to chemical energy. The chemical energy is then changed back into electrical energy when the cell is discharged.

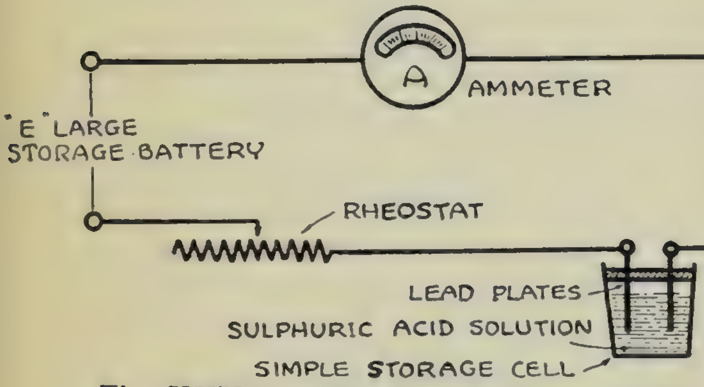


Fig. XXVIII. The Simple Storage Cell.

In charging, only Direct Current can be used. Most lighting circuits in our houses are alternating current which must not be used unless connected through a Rectifier. This device changes the alternating to Direct Current for charging purposes.

The positive terminal of a battery may be detected in several ways. It may be marked + or painted red. In automobile batteries the positive terminal is larger than the negative. The positive plate is a reddish brown color which may be seen if a glass battery jar is used. A "D.C." voltmeter may also be used if it has the polarity marked on the instrument. Other methods are also used but these are the most common.

QUESTIONS.

1. What happens when you pass a current through a storage cell?
2. What does the cell store up?
3. What is a Rectifier?
4. How may the positive terminal of a storage cell be determined?

JOB XXIX. STORAGE BATTERY TESTER.

Proposal. To test the charge in a storage cell with a battery tester (Hydrometer), and to measure the pressure of one storage cell, and also a battery of three cells.

Requirements. One 6 volt storage battery, one battery tester (Hydrometer), one low range voltmeter.

Procedure.

1. Examine the battery tester and notice the small float inside the syringe. This is really a hydrometer, that is, an instrument which indicates the density of a liquid.
2. Draw up enough liquid to float the hydrometer.
3. Note the charge as indicated on the scale at the level of the liquid.
4. Repeat for each of the cells.
5. Test the voltage of one cell, then two cells, then three cells.
6. Make a sketch of the top of the battery showing cells, terminals, stoppers, connections, etc.

NOTE: The positive terminal of an automobile battery is either marked +, or painted **red,** or is larger than the negative terminal.

LESSON.

It is very necessary to test the storage battery in an automobile from time to time. The word "battery" means a number of cells in the same way as a battery of guns means a number of guns. The "storage" cell differs in construction and operation from the "primary" cell in many respects. One of these is that it can be recharged, which you cannot do to the primary cell. It must not be tested with an ammeter, so be careful not to try this, or the ammeter will be destroyed. Storage batteries are tested with a specially designed battery tester. It consists of a hydrometer inside a syringe. The liquid in the cell is drawn up by the syringe into the glass. If the battery is charged, the small hydrometer inside floats high in the liquid, but when discharged it is nearly submerged. One storage cell gives a voltage of two volts. Automobile batteries are usually made up of three cells connected in series and therefore have a voltage of 6 volts. The principal care required by a storage battery is to keep it well charged and add pure distilled water, as required, to keep the liquid over the plates. It should be tested every two weeks with the battery tester.

QUESTIONS.

1. What is the difference between a "battery" and a "cell"?
2. How does the hydrometer tell the charge of a battery?
3. What is the voltage of one storage cell?
4. How many cells are there in most automobile batteries?
5. What is the voltage of an automobile battery?

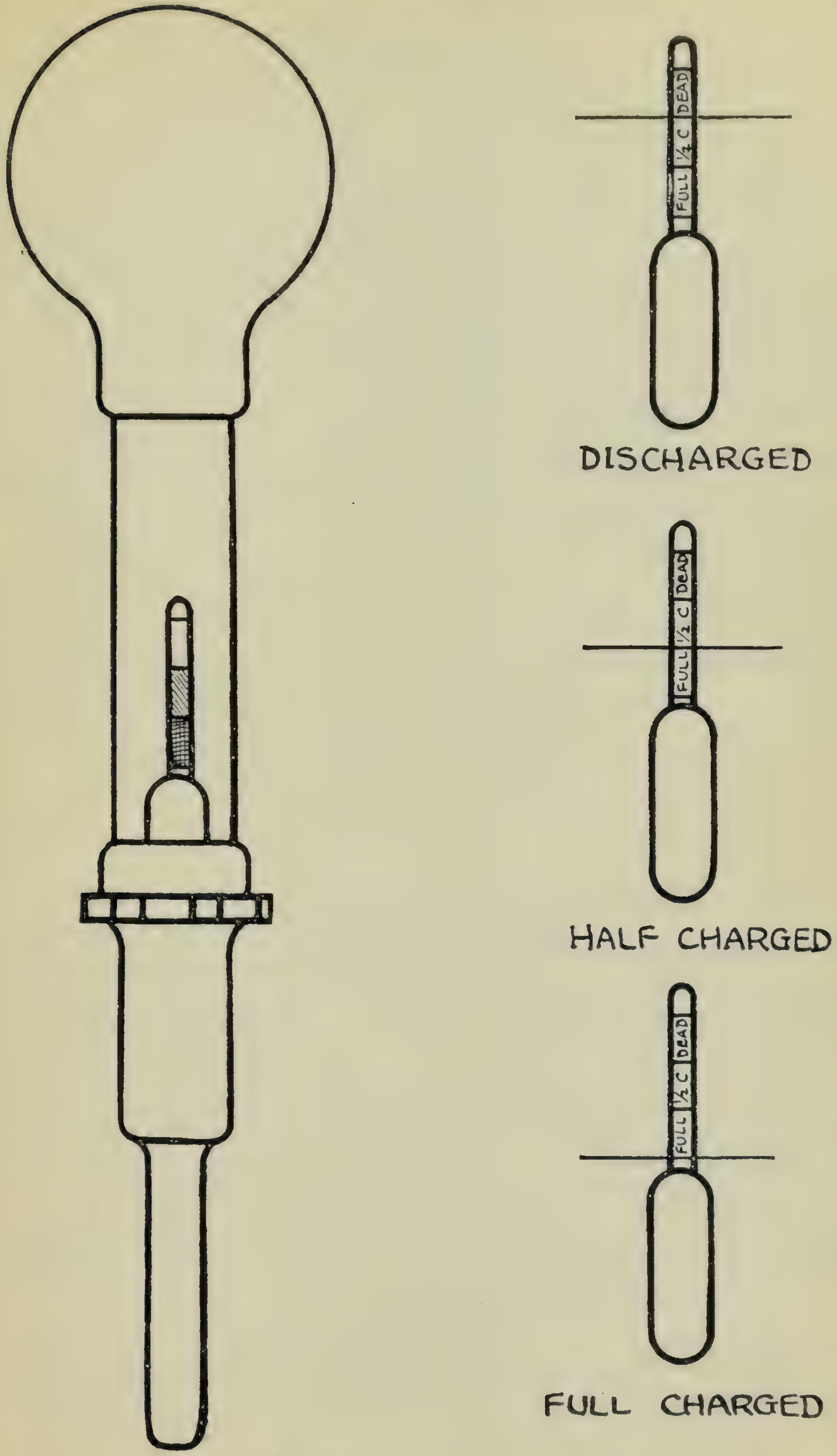


Fig. XXIX. Storage Battery Tester.

JOB XXX. ELECTROLYTIC RECTIFIER.

Proposal. To make a simple Rectifier.

Requirements. A small jar fitted with two electrodes, one aluminum and the other lead as shown in sketch. This jar is filled with a solution of borax or ammonium phosphate. A bank of three or four 60 watt lamps, a storage battery, ammeter and wire.

Procedure. Place electrodes in jar and connect to 110 volt A.C. lighting circuit, as in sketch. The lead-aluminum cell allows the current to flow only in one direction. The positive terminal of the battery must be connected to the aluminum electrode, which is the positive terminal of the electrolytic Rectifier. The resistance lamps retard the current and should be arranged so as to allow about one ampere to pass through the cell. If a standard battery is used, test **with a hydrometer** before and after charging for several hours.

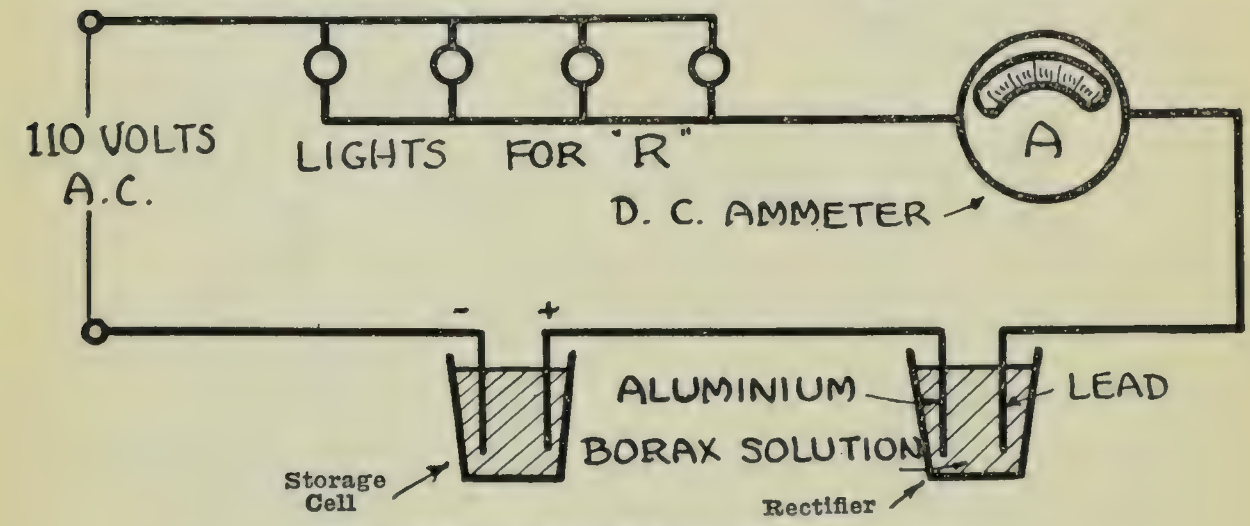


Fig. XXX. Simple Electrolytic Rectifier.

LESSON.

In explaining the purpose of the Rectifier it must be understood that alternating current is constantly reversing to and fro many times every second. If this current was passed through a storage cell, it would first charge the cell; when it reversed it would discharge again and the result would be no charge. The Rectifier acts like a traffic policeman who allows the traffic to pass in one direction only on a "one-way" street. The current is allowed to pass through the electrolytic Rectifier from the lead to the aluminum but not in the reverse direction. The current is not steady but goes in pulses. Nevertheless, it is one direction only, which is the main thing, and the storage cell or battery is charged.

A "trickle charger" is a small electrolytic Rectifier which keeps charging the battery with a very small current or "trickle". Other types of Rectifiers are the Tungar, the Mercury-Arc and the Magnetic Rectifier.

QUESTIONS.

1. Why can we not use alternating current for charging storage batteries?
2. What does the Rectifier do?
3. What is a "trickle" charger?
4. What other Rectifiers are there?

JOB XXXI. ELECTRIC LAMP.

Proposal.

To wire up an electric lamp.

Requirements.

A wooden lamp stand. (This may be turned up in the woodworking shop). Ten feet of silk lamp cord. One pull chain socket. One separable plug. One piece 1/8"x7½" gas pipe threaded at both ends. Two only 1/8" lock nuts.

Procedure.

Remove cap from socket and screw onto the gas pipe. Insert pipe down centre of the stem of the lamp and hold in position with lock nut at the bottom. Thread silk lamp cord through base and up the stem and wire into socket. Replace socket into cap. Attach plug to other end of lamp cord.

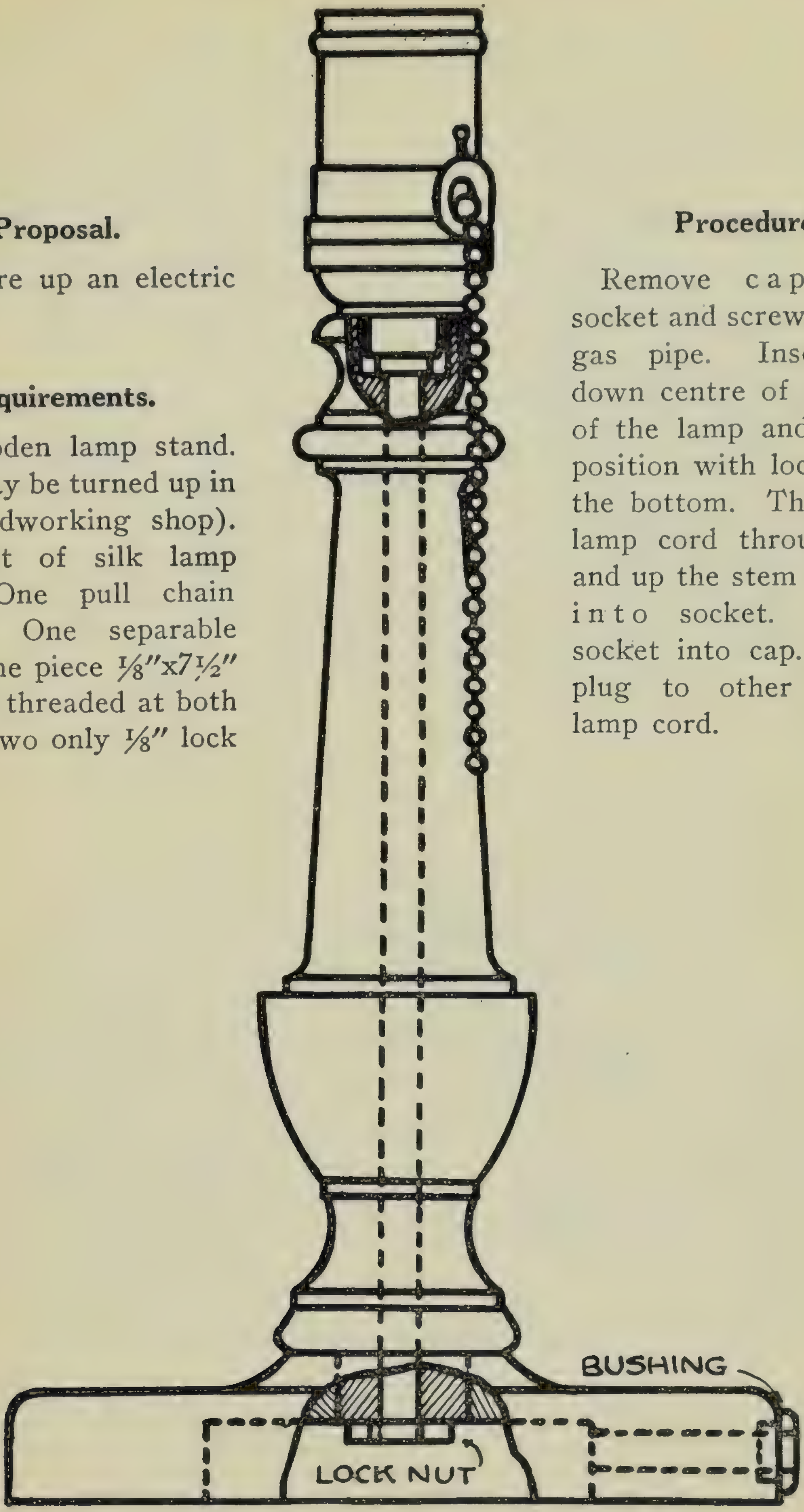


Fig. XXXI. The Electric Table Lamp.

JOB XXXII. WIRE SPLICING.

Proposal. To make electric wire splices.

Requirements. Two short pieces of No. 14 Rubber Covered Wire, a soldering iron, solder, soldering flux.

Procedure.

(a) **To make the Western Union Splice.**
Skin off about 3½″ to 4″ and clean the wire by scraping with a knife. Wrap one wire around the other as shown in the sketch so that it is mechanically tight. Now solder the joint. In doing so, apply a small amount of soldering flux and then run in the solder with the hot iron. Cover the splice with a layer of rubber tape and then with friction tape.

(b) **To make the Tap Splice.**
Bare the line wire at the point where branch is to be attached. Skin and clean the end of the branch wire. Wind the branch wire onto the line wire as shown in the figure. Solder the joint and cover with rubber and friction tape as before.

(c) **To make the Rat-Tail Splice.**
Simply skin and clean the ends of the wire and twist together, turning the ends over as shown in the figure. Solder the joint and cover with rubber and friction tape.

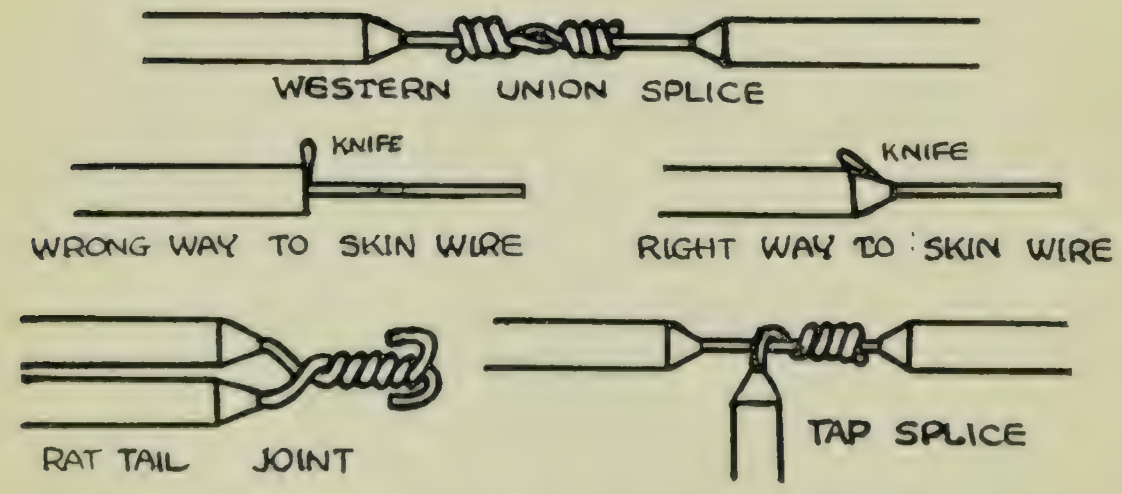


Fig. XXXII. Wire Splices.

LESSON.

It is of extreme importance in all electrical wiring work that every splice be mechanically and electrically sound. Poor joints always cause trouble. To be mechanically strong, one wire must be wrapped around the other a number of times so that there is no loose play between them. Then to make sure of the electrical contact being perfect, the joint is soldered. The solder must be "sweated in" so that the whole joint is perfectly tinned into one solid piece. Next, the insulation must be properly applied. Friction tape should not be considered as insulation. Rubber tape must be applied first. The friction tape is put on to protect the rubber and make a strong outside cover.

In skinning the wire the knife must be held at a slant to avoid making sharp nicks in the wire. If the wire is nicked and then bent it is liable to cause the wire to split, and in time, due to vibration or contraction and expansion, the wire end would break off.

The Western Union Splice is made for all straight running joints. The Tap joint is made for all branch leads. The Rat-Tail Splice is used in fixtures and in junction boxes, etc., where two wires are already brought out coming from two different directions. Note that the ends of the wire are bent over so they will not cut through the insulation.

QUESTIONS.

1. Why must a number of turns be made in all splices?
2. Why must they be soldered?
3. What is the difference between rubber tape and friction tape?
4. What is the purpose of each?
5. Why must the knife be held at a slant when skinning wire?
6. Why must the wire be cleaned thoroughly?
7. In the Rat-Tail Splice why must the wire ends be bent over?
8. Name the three splices and state where each is used.

JOB XXXIII. THE BELL RINGING TRANSFORMER.

Proposal. Instead of using batteries the bell is to be made to operate from the 110 volt lighting circuit through a transformer.

Requirements. Bell ringing transformer, bell, push button, bell wire.

Procedure. Connect up according to sketch. Notice the heavy insulated wire used to connect to the 110 volt lighting circuit. This is different from bell wire. Test the circuit by connecting transformer to 110 volt test line under the direction of the instructor.

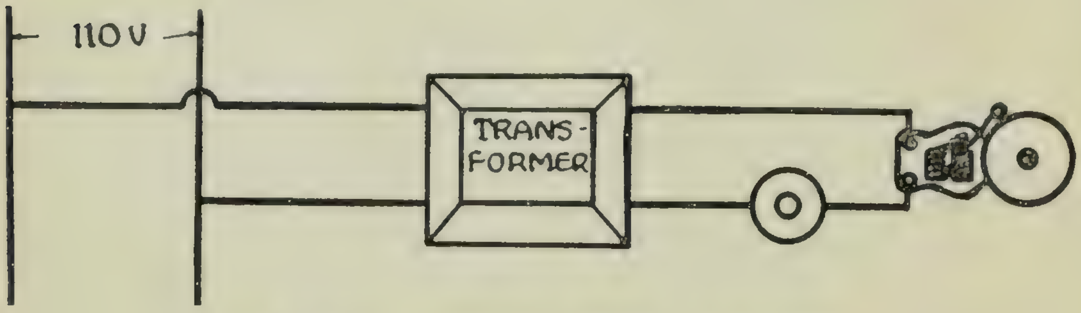


Fig. XXXIII. The Bell Ringing Transformer.

LESSON.

A bell ringing transformer is a device for changing the voltage of the lighting circuit from 110 volts down to 8 volts for bell ringing service. Signal bells are made for low voltage such as is obtained from two or three dry cells. However, cells run down in about a year and the bells will not operate unless new cells are bought and put in. When transformers are used this is not necessary, as transformers should last for years.

When installing a transformer, care must be taken when connecting to the lighting circuit. There are two heavily insulated wires brought out from the transformer. These are the 110 volt leads. They should be soldered on to the wires and the splices properly taped up. Ordinary annunciator wire is used for the low voltage bell circuit in the same way as all bell circuits.

QUESTIONS.

1. What is a bell ringing transformer?
2. What is the advantage of using a bell ringing transformer instead of a battery?
3. Why not connect the bell direct to the lighting circuit?
4. Why are wires to the lighting circuit heavily insulated as compared with annunciator wire?
5. Why is it unnecessary to use heavily insulated wire for the bell circuit?

JOB XXXIV. FUSES.

Proposal. To locate burned out fuses and to replace them with good ones.

Requirements. A fused switch block, a cleat receptacle, a number of good and burned-out fuses, an electric lamp and two short pieces of No. 14 R.C. wire, four wood screws 1¼″ long, an electric heater—6 amperes.

Procedure.

1. Wire up according to sketch.
2. Have wiring checked by instructor.
3. Connect leads to 110 volt circuit with switch open.
4. Having inserted lamp, close switch and see if lamp burns; if so, fuses are good.
5. Replace fuses with a number of others, and separate the good from burned-out ones.
6. Place a one-ampere fuse in circuit and connect heater. Fuse should blow out, because heater draws 6 amperes, which is too heavy for the fuse.
7. Examine some renewable fuses and also some cartridge fuses; make sketches of each and find out how they are used.

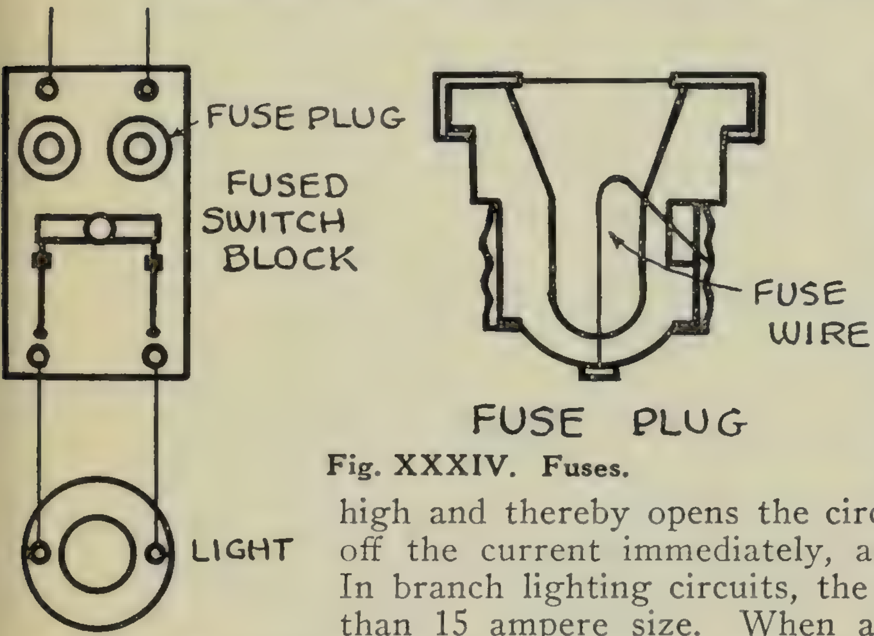


Fig. XXXIV. Fuses.

LESSON.

Electric circuits must be protected against a too high current. An excessive current causes overheating of the wires which ruins the insulation and may cause fire. A fuse is simply a short piece of fusible wire which melts when the current gets too high and thereby opens the circuit. This, of course, cuts off the current immediately, and the danger is averted. In branch lighting circuits, the fuse should not be larger than 15 ampere size. When a fuse burns out, the first thing to do is to look for the cause. It may be a defective iron-cord, or too heavy a load, such as a large hot-plate or other device. Having removed the cause, replace the burned-out fuse with a new one. There is a very dangerous practice of inserting a coin behind the old fuse, or otherwise **jumping the fuse.** Never do this as it may cause a fire.

There are two types of fuses: plug fuses, which are used on circuits up to 30 amperes; and Cartridge fuses, used for larger circuits, such as for motors or main fuses. These may be as large as 500 ampere capacity.

QUESTIONS.

1. What is the purpose of an electric fuse?
2. How does the fuse operate?
3. What is the fusing limit in a branch lighting circuit?
4. What is the proper procedure when a fuse burns out?
5. What is the danger of "jumping" a burned-out fuse?
6. What is the largest size plug fuse?
7. What type of fuse is used for circuits carrying heavier currents?

JOB XXXV. KNOB AND TUBE WORK—ONE LAMP.

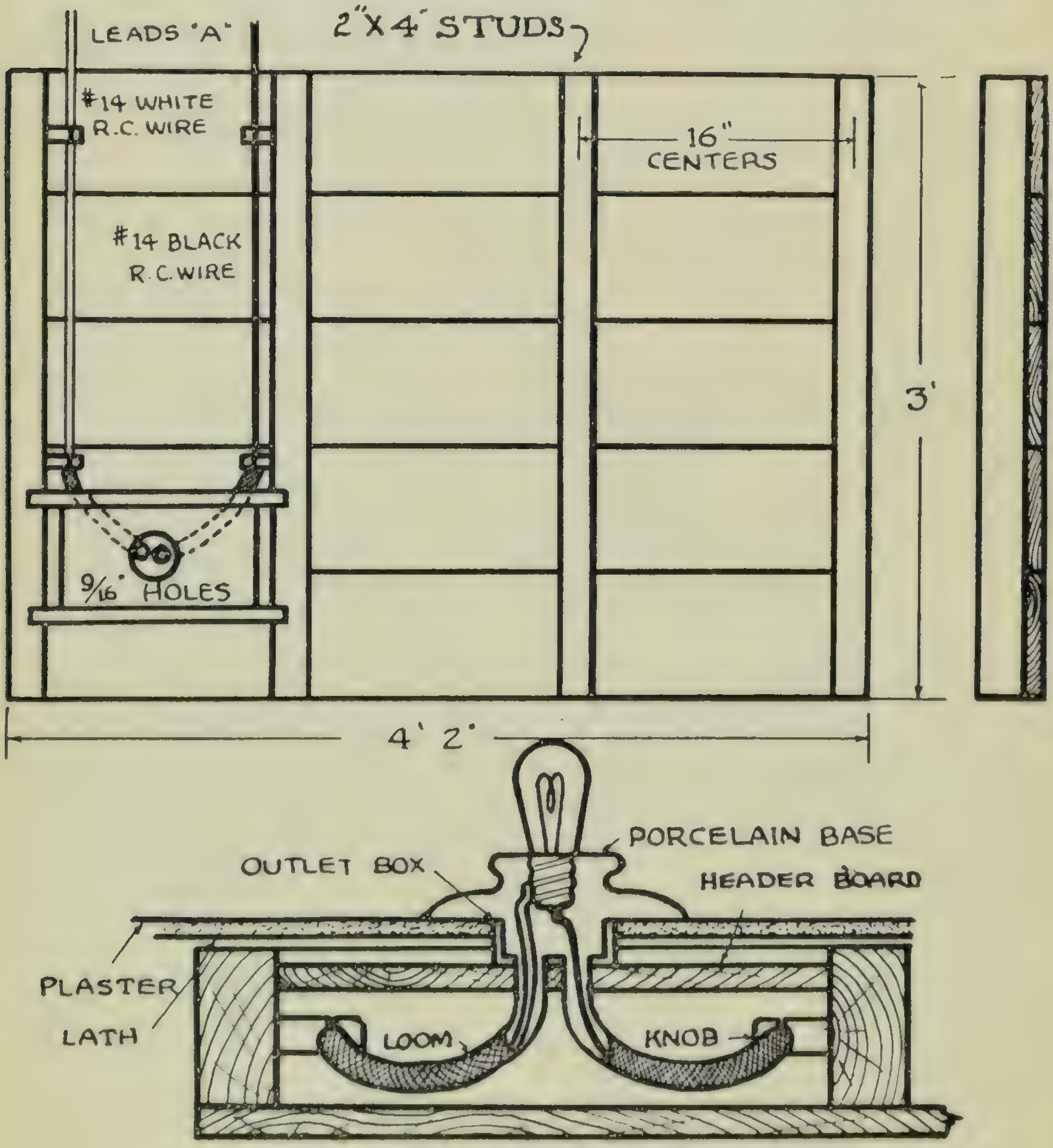
Proposal. To connect up a 110 volt lamp as in a house, using knobs.

Requirements. Wiring board, header board, four split knobs and screws, round shallow outlet box and two screws, one porcelain light receptacle, two pieces loom 10″ long, 3½′ white No. 14 R.C. wire, 3½′ black No. 14 R.C. wire.

Procedure.

"Roughing In".

1. Fix header board in place.
2. Run wire from start "A" to board using knobs to hold wire in place.
3. Screw round outlet box in centre of header board.
4. Place loom on wires and pass through knockout holes in box (loom must run from last knob into outlet box—See Fig. XXXV.) Roughing in must be checked by instructor before proceeding.



DETAIL OF FIXTURE INSTALLATION

Fig. XXXV. Knob and Tube Work—One Circuit.

This drawing shows detail of wiring boards used for knob and tube work and all other wiring jobs in this book.

Finishing.

5. Place beaver board or plaster board on top of lath, (imagine this to be plaster), having a hole cut in it the same size as box.
6. Fix wires under binding screws of fixture and coil wire ends into the box.
7. Screw fixture in place.
8. Test circuit (under direction of instructor).

LESSON.

On account of the danger from fire and shock, 110 volt wiring for lighting service must be very carefully done. No. 14, rubber covered wire is the standard size. It must not be allowed to carry more than the normal amount of current which is about 15 amperes. Overloading causes the wires to heat up which destroys the rubber insulation. The wires must be well insulated to prevent anyone from getting a shock, and also spaced well apart so there will be no possibility of them coming in contact with one another. The fire insurance underwriters and all cities have very strict rules on this account. These rules are the result of many years' experience and study, some of which are given here in short form.

Rule 1. Knob and tube system of wiring is allowed only in frame buildings used for residential purposes. It is not allowed in public buildings, storehouses, schools or shops.

Rule 2. In wiring houses in the "two-wire" system, one wire is black and the other white. The black is known as the "outside" or "live" wire. The white is called the "neutral" or "grounded" wire. These wires must be spaced not less than 4″ apart.

Rule 3. All wires must be supported on porcelain knobs not less than 1″ away from the woodwork. The knobs must be spaced on the studding or joists not more than 4½′ along the wire.

Rule 4. Each outlet must be placed in a metal loom box on a "header board" nailed between the studding or joists. This box provides a housing for the wire ends.

Rule 5. Loom must be placed over all wire loops between the outlet box and the first supporting knob.

QUESTIONS.

1. Why must great care be taken when wiring lighting circuits?
2. What is the standard size of wire for lighting circuits?
3. What is the normal current for this wire?
4. What happens when wires are made to carry more than normal current?
5. Why must lighting wires be well insulated?
6. Where is the knob and tube method of wiring allowed?
7. How far apart must the black and white wires be spaced?
8. How must lighting wires be supported?
9. How are the outlet wires brought out?
10. How must the loops into the outlet box be protected?

JOB XXXVI. KNOB AND TUBE WORK.

ONE LIGHT AND ONE SWITCH.

Proposal. To wire up a light and snap switch.

Requirements. Wiring board, two header boards, ten split knobs and screws, four porcelain tubes, round outlet box and two wood screws for same, one light receptacle, four pieces loom (10″ long), one snap switch and two wood screws for same.

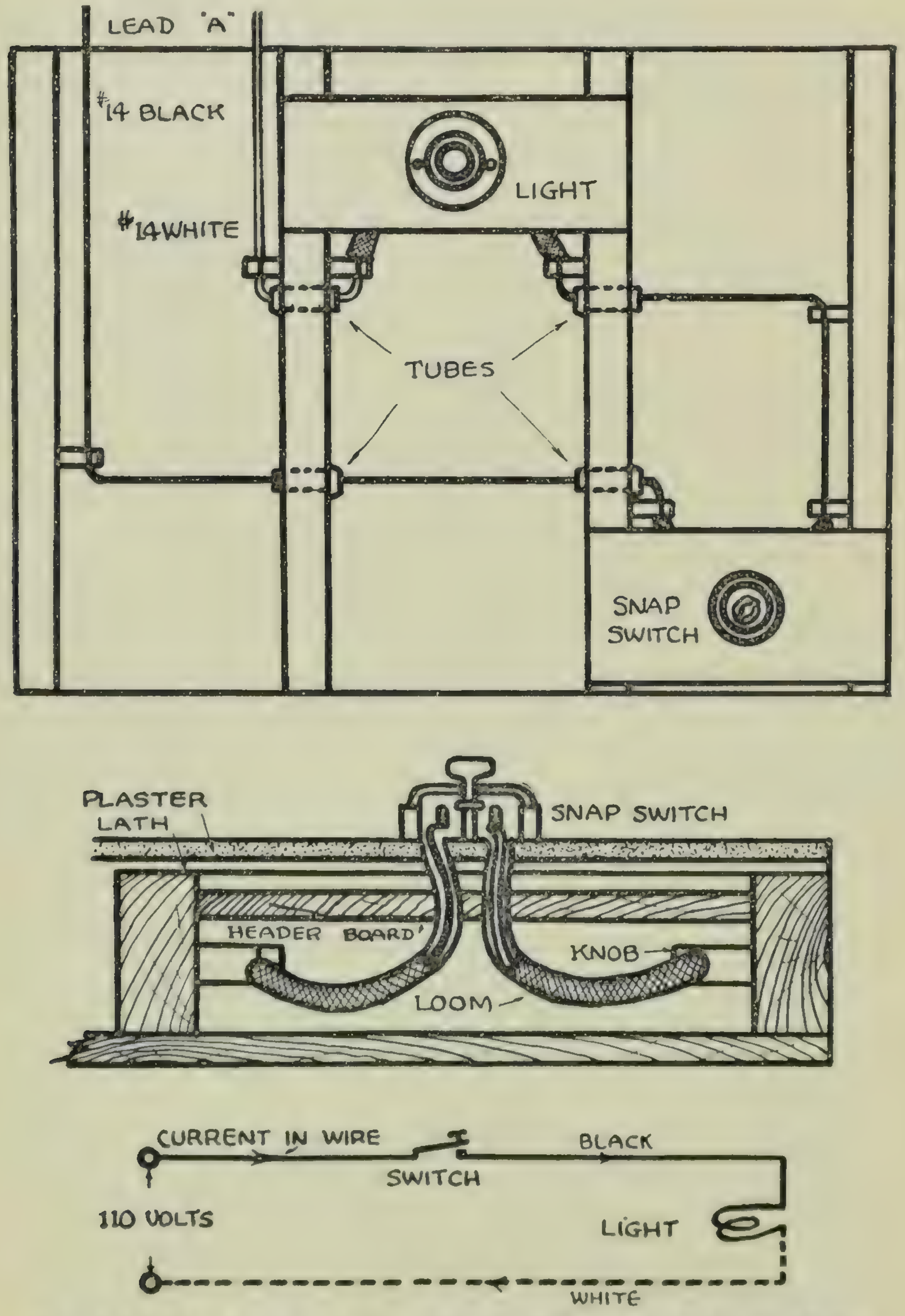


Fig. XXXVI. Knob and Tube Work—One Light and One Switch

Procedure.

1. Fix headers in place.
2. Run black wire from start "A" to switch and then to light. (Note: switches are always placed in the black wire side of the line.)
3. Run white wire to light (see Fig. I.)
4. Screw outlet box in centre of the header board.
5. Place loom on wires and pass through headers. Roughing in work must now be checked by instructor.
6. Install lighting fixture as in Job XXXV.
7. Install snap switch. Put beaver board over header board. Bring wires out through two holes and into switch. No outlet box is used here. Screw switch into place using long screws. Screw wires under binding posts and replace cover.
8. Test circuit (under direction of instructor).

LESSON.

A switch is a device for opening or closing a circuit. Lighting switches are made to snap on and off quickly. This prevents any spark from burning the contacts. No outlet box is required for a snap switch. The loom is brought through the header, lath and plaster to the bottom of the switch. Here are the additional rules for this circuit:—

Rule 6. All switches must be placed "in" the black wire line. No switch or fuse is allowed in the white wire or neutral line; it must be "solid" from the street to the light.

Rule 7. When wires are passed through wooden partitions, porcelain tubes must be used, the head being placed at the bend, if any.

QUESTIONS.

1. What is a switch for?
2. Why is a switch made to "snap" on and off.
3. There are two lines running to the light, the "white" and the "black." In which of these is the switch placed?
4. How are wires passed through wooden partitions?
5. What is the rule as regards the installing of the white or "neutral" wire.

JOB XXXVII. KNOB AND TUBE WORK—FLUSH SWITCH.

Proposal. To change the "snap switch" in Job XXXVI. to a "flash switch".

Requirements. (See Job Sheet XXXVI.) also one flush switch, switch box and switch plate complete, one header board with square hole for switch box.

Procedure. You have done Job XXXVI.; now see if you can take out the snap switch and put in the flush switch without any further directions. Examine the flush switch and board and plan your work carefully. Test out (under direction of instructor).

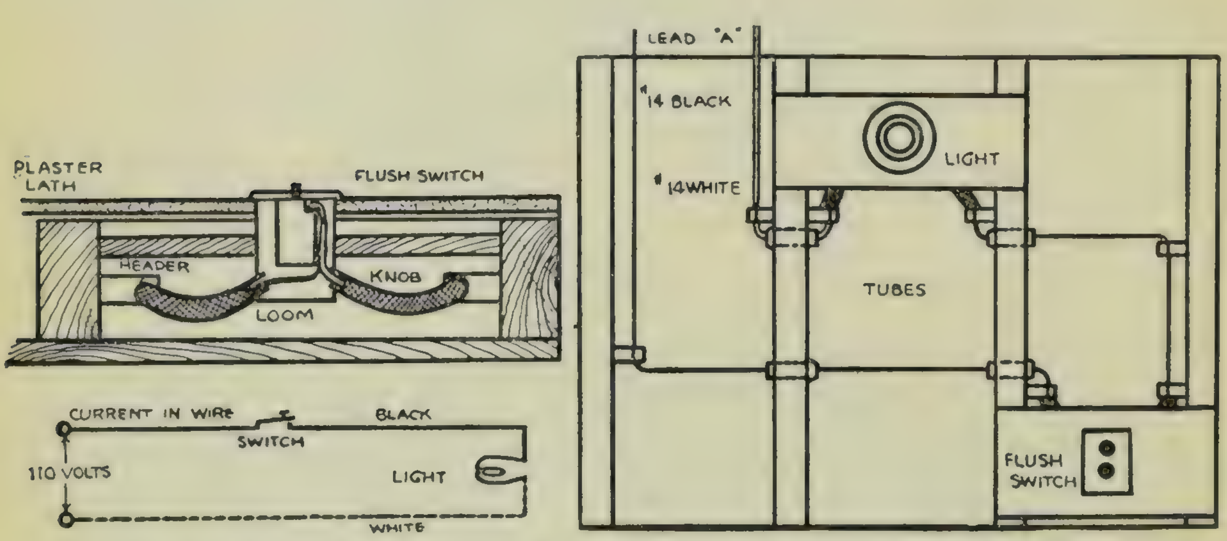


Fig. XXXVII. Knob and Tube Work—Light and Flush Switch.

LESSON.

The flush switch is a much better type than the snap switch. It is better protected and has a neater appearance. Although it costs a little more, it makes an altogether better job. The switch is contained in a special metal loom box supported in a header board. There is a white button indicating the "On" and a black button the "Off" position.

Rule 8. All flush switches must be placed in approved metal switch boxes.

QUESTIONS.

1. What is the advantage of the flush switch, in regard to safety and appearance, over the snap switch?
2. Which is the easier to install?
3. Which is the more expensive?

JOB XXXVIII. KNOB AND TUBE WORK—CONVENIENCE OUTLET.

Proposal. To wire up a convenience outlet.

Requirements. Seven feet No. 14 white wire, seven feet No. 14 black wire, seven knobs and screws, four tubes, one header board with square hole to fit square loom box, one convenience outlet to fit box, one cover for convenience outlet, one square loom box.

Procedure. Make a bill of material. Wire up as in sketch with as little assistance as possible. Examine fittings and see how connections are made. Test out under direction of instructor.

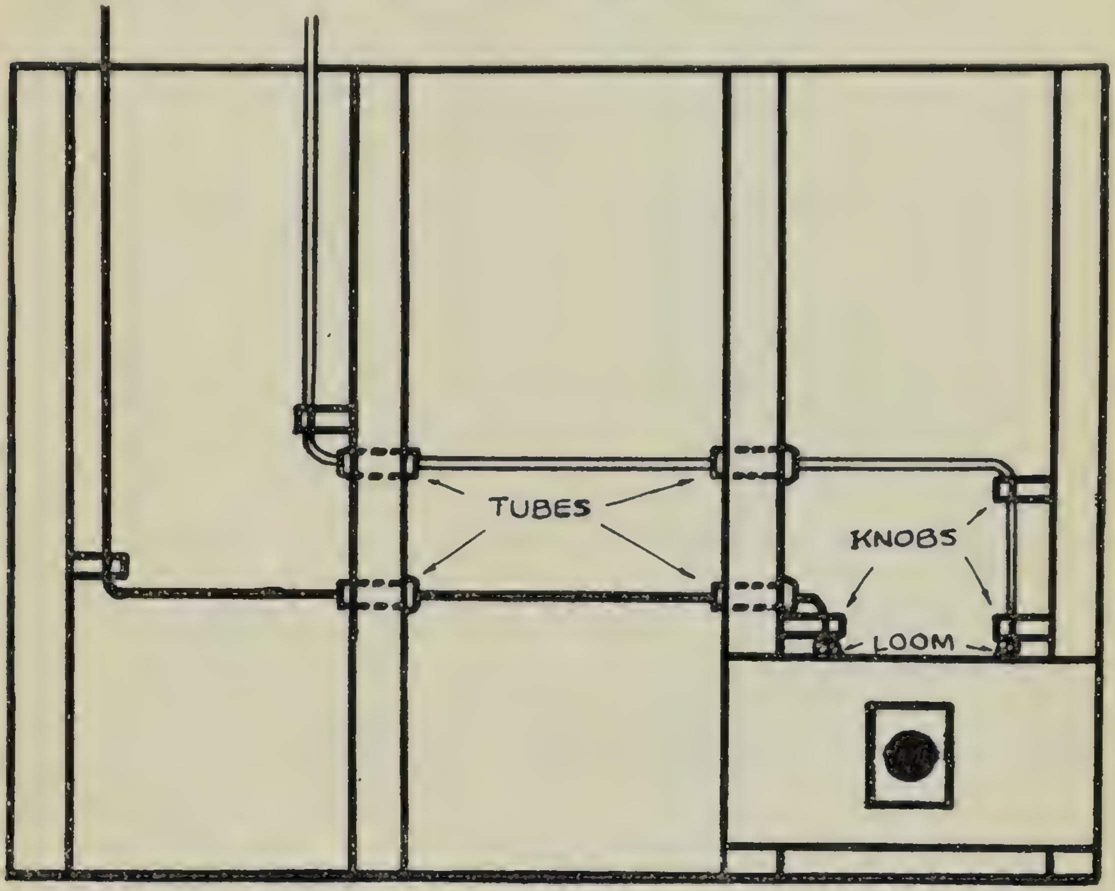


Fig. XXXVIII. Knob and Tube Work—Convenience Outlet.

LESSON.

A convenience outlet is a fitting which provides for the connecting of lamps, household appliances and other electrical devices to the electric circuit. They are placed in the wall or base board of a room. Most new houses have a number of these about the house. Here is a list of rooms and appliances that may be used:—

Kitchen—Electric iron, stove.
Dining Room—Toaster, coffee percolator, vacuum cleaner.
Sitting Room—Standard lamp, vacuum cleaner, radio.
Bedroom—Curling irons, table lamp.
Basement—Washing machine.

Rule 9. A convenience outlet must be placed in an approved metal loom box.

QUESTIONS.

1. What is a convenience outlet?
2. Where are they usually placed?
3. Make a list of rooms and the appliances that may be used in each.

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JOB XXXIX. KNOB AND TUBE WORK—TWO LIGHTS.

Proposal. To wire up two electric lights on one circuit.

Requirements. Ten knobs and screws, five tubes, nine feet No. 14 white R.C. wire, nine feet No. 14 black R.C. wire, two header boards, two round outlet boxes, two receptacle covers for same, four pieces of loom, soldering iron, solder and soldering paste, rubber tape. friction tape.

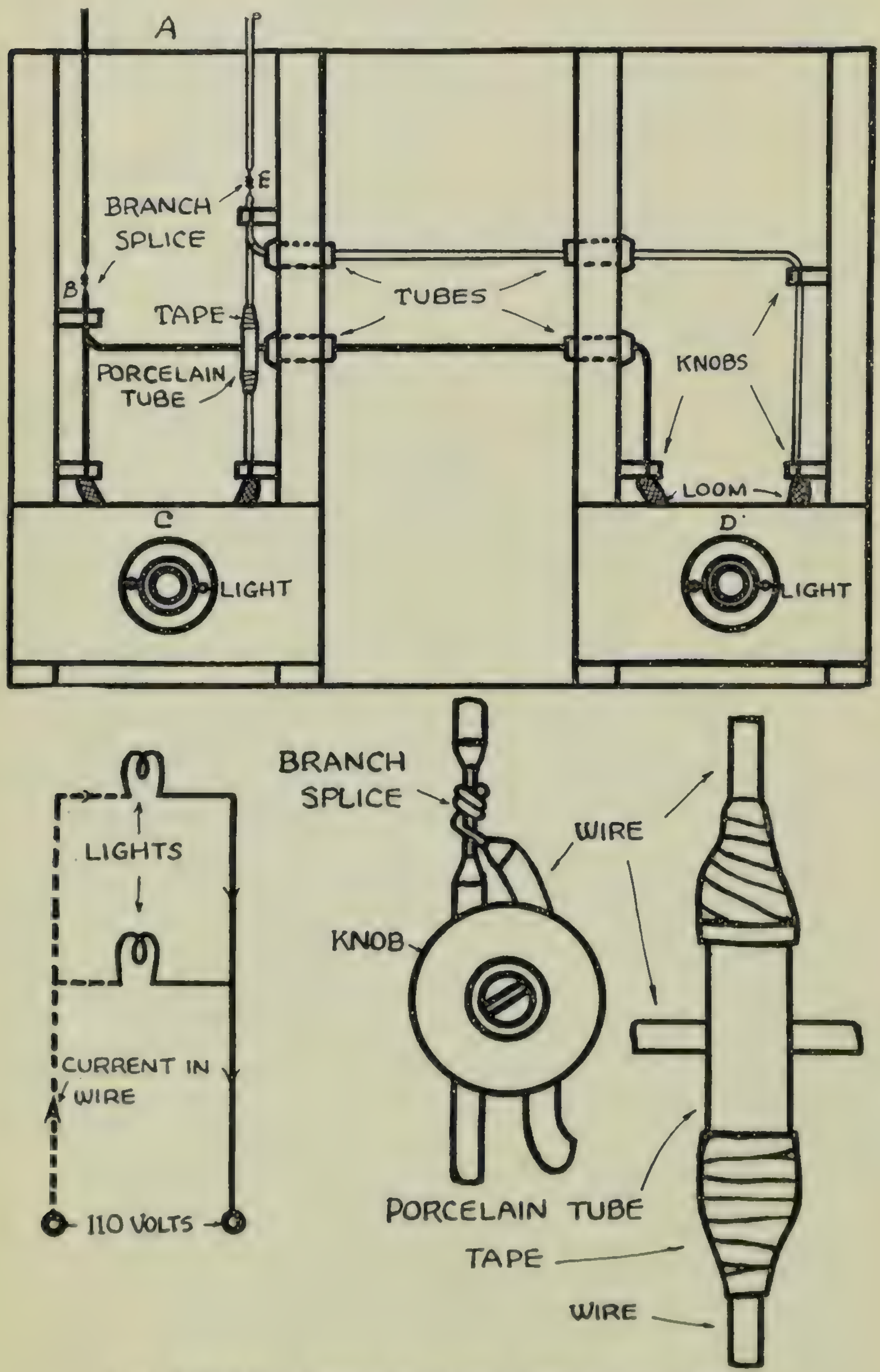


Fig. XXXIX. Knob and Tube Work—Two Lights.

Procedure.

"Roughing In".

1. Place header boards in position.
2. Screw on round outlet boxes.
3. Run white and black wires from A to C, leaving a tube on white wire for crossover.
4. Run black wire from knob at B to light at D, leaving about 6″ for splice.
5. Run white wire from knob at E to D leaving 6″ for splice. (NOTE: Splices must be supported with knobs as shown in Fig. XXXIX.)
6. Tape both ends at crossover tube with friction tape so as to prevent slipping.
7. Make tap splices at B and E, and solder and tape. Have instructor inspect work before proceeding.

Finishing.

Tack beaver board or plaster board into place over the header board, leaving an opening over round loom box. Connect wires to porcelain light receptacles and mount them in place. Place lamps in receptacles and test out.

LESSON.

All lights on one circuit are wired in parallel. This job involves two new operations. First, splicing in the branch circuit; second, crossing over the white and black wires. For simplicity no switches are included, but on a large wiring board or booth this may be done. The switches are placed in the black wire line as in Jobs XXXVI. and XXXVII.

Rule 10. All splices must be soldered and insulated with rubber and friction tape.

Rule 11. All splices must be supported by knobs so that no strain is placed on the splice.

Rule 12. When wires of opposite polarity are made to cross one another they must be kept separate by a tube or loom placed over one of the wires and held in position with friction tape.

Rule 13. When wires are brought close to water pipes, heating flues, or other metal conductors, they must be protected with additional insulation, such as tubes or loom.

QUESTIONS.

1. How are lights on one circuit connected?
2. What are the rules applying to the method of splicing-in branch circuits?
3. How are switches placed in branch circuits?
4. What precaution must be taken when wires of opposite polarity are made to cross one another?
5. How are wires carried over water pipes or other metal conductors?

JOB XL. KNOB AND TUBE WORK.

TWO STATION CONTROL OF ONE LAMP.

Proposal. To wire up a three-way circuit. This circuit is used when it is required to turn off or on a light from two places, such as a hall light, with a switch upstairs and one downstairs.

Requirements: Two three-way snap switches, one light receptacle, six tubes, eleven knobs, six pieces loom, twelve feet No. 14 black R.C. wire, six feet No. 14 white R.C. wire, three header boards, three pieces beaver board.

Procedure.

1. Examine three-way switch carefully. Notice there are four connecting posts on the switch, two of which are bridged together at the back of the switch.
2. Wire up as indicated in Fig. XL.

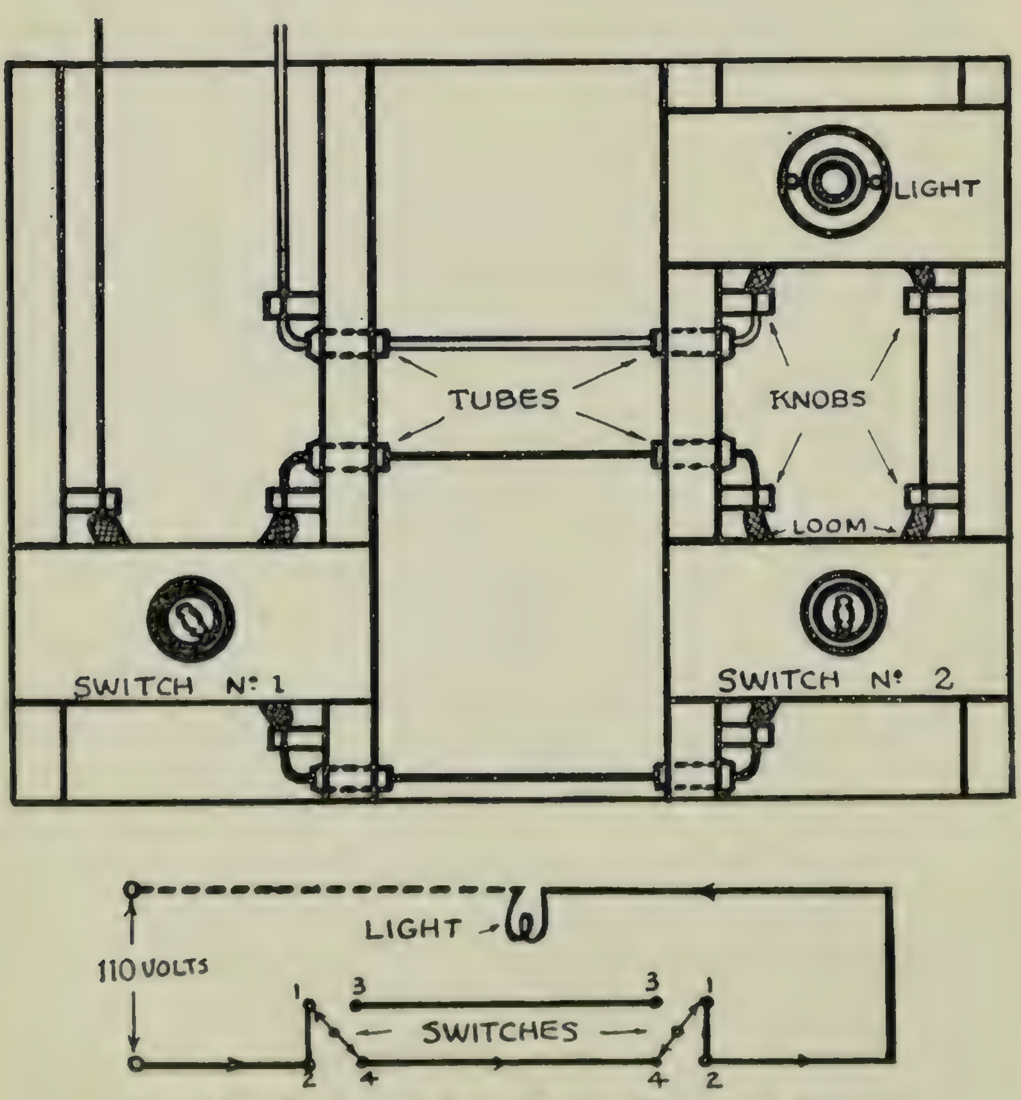


Fig. XL. Knob and Tube Work—Three-way Circuit.

LESSON.

It is often necessary to control a lamp from two points, the most common instance being on a stairway. The light may be switched "off" or "on" at both the head and foot of the stairs. Use is made of a three-way switch. This switch has four posts which are numbered in the diagram. It operates so as to cross-connect these posts (from 1 to 4, or 2 to 3) by each half turn of the switch blade. If you examine the switch carefully you will notice that two of the posts are bridged together so as to form a common terminal. This is connected to the main line. The other two are connected to corresponding terminals on the other switch by two switch lines. If both switches are connected to the same switch line the light is "on", but if on opposite switch lines the light is "off". Thus the light can be turned "on" or "off" at either point by turning the switch to the same or opposite line to which the other switch is connected. This method is also used in garages, long corridors, auditoriums, etc.

QUESTIONS.

1. How does a three-way switch differ from a single pole switch?
2. Make a diagrammatic sketch of a three-way circuit, i.e., a light operated by two three-way switches.
3. Where is this system most commonly used?
4. Explain briefly the operation of the three-way circuit.

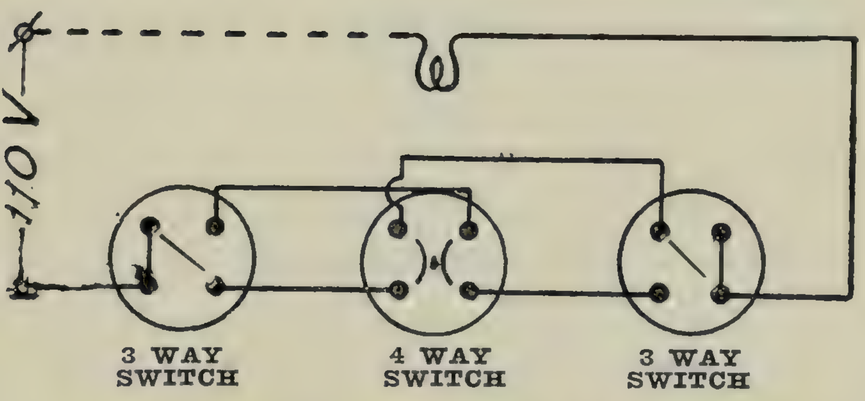


Fig. XL(a). Four-way Circuit showing a light operated by three separate switches.

JOB XLI. CONDUIT WORK—LIGHT AND SWITCH.

Proposal. To connect a light and a switch using conduit and condulet fittings.

Requirements. Eight feet of black and six feet of white No. 14 R.C. wire, three only 6″ x ½″ conduit nipples, three feet ½″ conduit pipe, one only ½″ E condulet, one only ½″ H condulet, one only LR condulet, one only ½″ T condulet, one only 3¼″ Octagonal outlet box, two only ½″ lock nuts, one only ½″ bushing, two blank covers, one only H condulet switch box, one snap switch, one porcelain receptacle box cover, one two-hole porcelain condulet cover, two pipe clips and screws.

Procedure.

1. Assemble conduit and fittings as in sketch. (Unless the work is to be permanent, it is not necessary to use a pipe wrench.)
2. Draw wires through the pipe, putting switch on the black wire side as usual.
3. Connect switch, receptacle, and replace all condulet covers.
4. Have job inspected by instructor and test out.

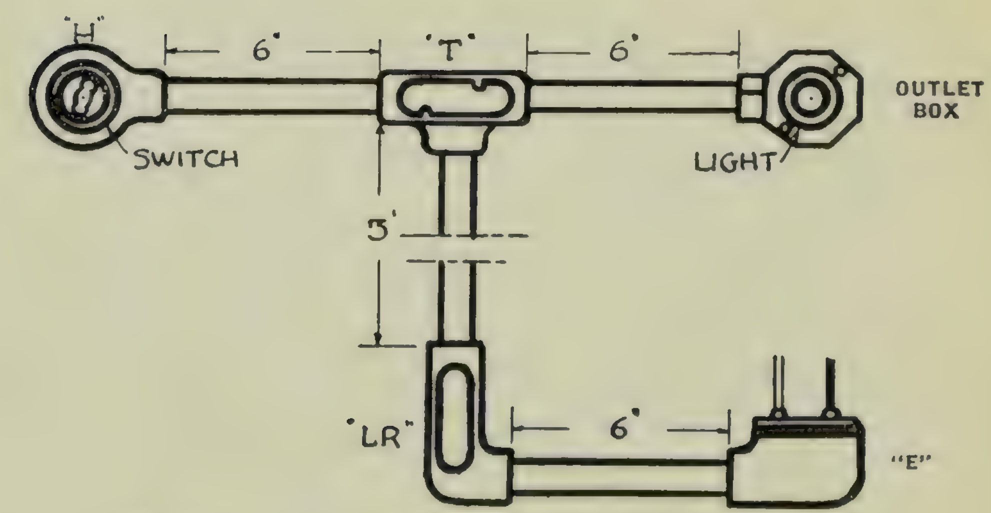


Fig. XLI. Conduit Work—Light and Switch.

LESSON.

Rigid conduit is the safest and best method of electric wiring. It protects the wires from injury and moisture, prevents the spread of fire in case of short circuit, and prevents anybody from coming in contact with live wires. Hence in many cities it is the only method allowed in public buildings such as schools, churches, office buildings, etc., and practically everywhere except in private dwellings of wooden frame construction. It is more expensive than knob and tube work, but this is the only disadvantage. Conduit pipe differs from water pipe in that all burrs are removed from the inside, the inside is enamelled and outside galvanized. It is also more ductile, that is, it can be bent without splitting or cracking. The following are some of the rules applying to the use of conduit work:—

1. When the pipe is cut, the ends must be reamed so as to remove all sharp edges.
2. Only braided rubber covered wire must be used.
3. No wire splices are allowed inside the conduit pipe. Splices must be made in metal junction boxes.
4. Only approved standard fittings are allowed to be connected.
5. The conduit pipe work must be continuous throughout the building and well "grounded" to a water pipe or other suitable "ground".
6. Where conduit enters metal boxes, the box must be securely clamped with lock nuts and a bushing placed on the end of the pipe.

QUESTIONS.

1. What are the advantages of conduit wiring?
2. What disadvantage is there?
3. Where is conduit pipe mostly used?
4. How does conduit pipe differ from water pipe?
5. What is the rule in regard to the position of splices in conduit wiring?
6. How are condulet fittings attached to the conduit pipe?
7. How are metal boxes attached to the conduit pipe?

JOB XLII. METAL MOULDING—LIGHT AND SWITCH

Proposal. To connect a light and switch using metal moulding.

Requirements. Eight feet black and six feet white No. 14 R.C. wire, three pieces (6″ long) metal moulding, one piece (3′ long) metal moulding, one only switch fixture and snap switch, one only receptacle fixture, one only entrance fixture, one only metal mould "L", one only metal mould "T", three metal mould clips and screws.

Procedure. Assemble as in conduit job. You can discover for yourself by trial how the various pieces are put together. When complete, have inspected and test out.

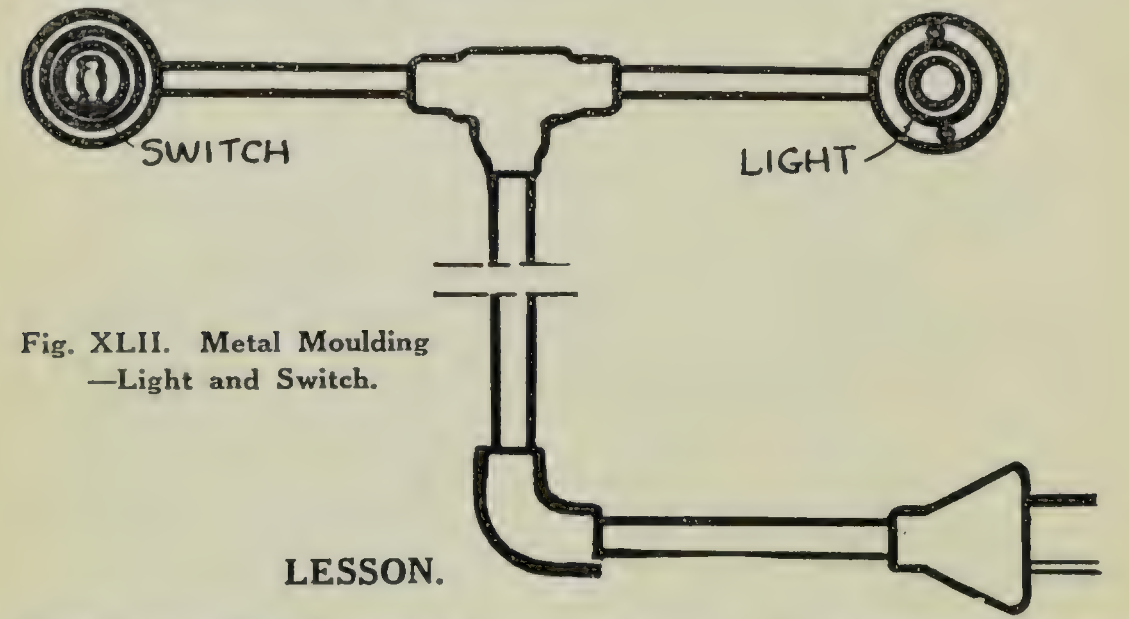


Fig. XLII. Metal Moulding —Light and Switch.

LESSON.

Metal moulding is used for surface work. It is permissible in most places where rigid conduit is required, provided there is no danger of moisture. There are many places such as furnished offices, stores, etc., where new extension circuits are required. Metal moulding makes a neat, safe method of wiring. It can be connected to conduit pipe by special fittings. Only No. 14 wire is allowed so it cannot be used for circuits requiring larger size wire. All kinds of fittings are manufactured and they are easily attached. It is more costly than conduit pipe but it is so quick and simple to install that it is really cheaper to use.

Rules for Metal Moulding.

1. Must never be used in damp locations.
2. Not more than four No. 14 B. & S. guage rubber covered wires are allowed in metal moulding.
3. No wire splices are allowed to be drawn into the moulding.
4. Metal moulding must not be concealed behind plaster walls, etc., and when passing through wall partition and floors, conduit pipe should be used unless special permission to depart from this rule is given by the inspector.

QUESTIONS.

1. Where is metal moulding used?
2. In what special locations must metal moulding not be used?
3. What is the largest wire allowed in metal moulding?
4. How many of these wires are permissible?
5. What are the advantages and disadvantages of metal moulding as compared with conduit pipe?

JOB XLIII. FLEXIBLE CONDUIT.

Proposal. To connect up a light and switch, using flexible conduit.

Requirements. Two pieces ½″ x 6″ flexible conduit, one piece ½″ x 3′ flexible conduit, three 3¼″ outlet boxes, one "E" condulet, six connectors for ½″ flexible conduit, five ½″ lock nuts, one switch-adapter cover for 3¼″ box, one blank cover for 3¼″ box, one porcelain receptacle cover, one porcelain condulet cover—two-hole, five feet No. 14 R.C. wire—white, seven feet No. 14 R.C. wire—black.

Procedure. If conduit has to be cut, clamp in vice and use hack-saw. Attach connectors to ends of conduit and connect to boxes as in sketch. Use a lock nut at each connection. Pull wires through to switch and light, and connect up in the usual manner. Have job inspected and test out.

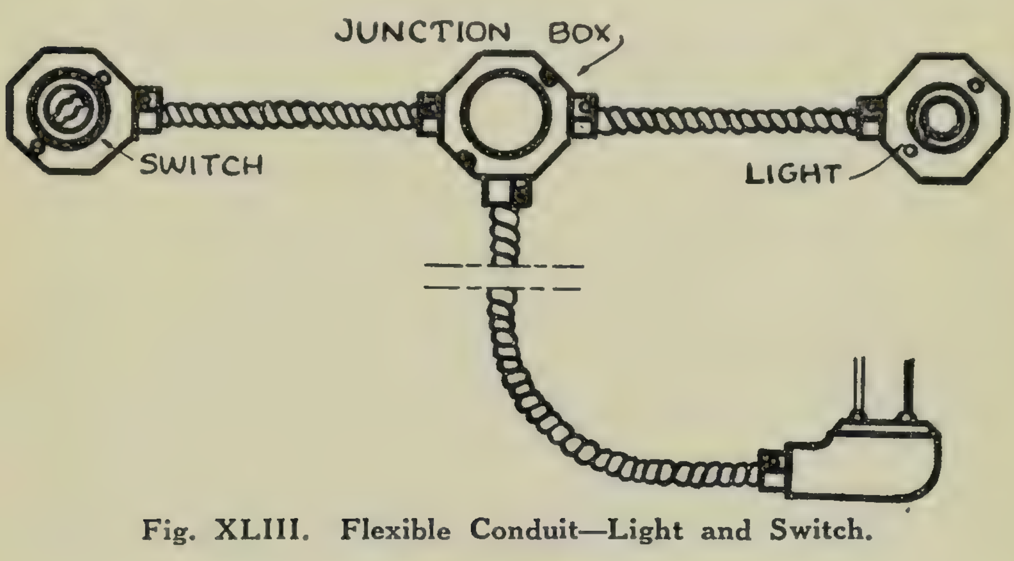


Fig. XLIII. Flexible Conduit—Light and Switch.

LESSON.

Flexible conduit is used in wiring finished buildings; for short awkward runs where rigid conduit would not be practical; for connecting to electrical devices which require limited movement to and fro, such as motors on sliding bases, electric stoves, etc. It is not moisture proof, and can only be used in dry places. It may be concealed, however, in the same way as conduit pipe, but as it is more expensive, it is not used unless it is necessary. The same wiring rules apply as for rigid conduit pipe.

NOTE: There is another method of wiring by the use of flexible armored cable. It is similar in appearance to flexible conduit, but the wires are inside ready for connecting. It is used very extensively, but as it is rather difficult to handle, no job is given in this book.

QUESTIONS.

1. What are the special uses of flexible conduit?
2. How does it compare with rigid conduit in regard to cost, damp places, wiring rules?
3. What is flexible armored cable?

JOB XLIV. TO MEASURE RESISTANCE.

Proposal. To measure the resistance of an electric bell by measuring the volts applied and the amperes delivered to it.

Requirements. A low range ammeter, a low range voltmeter, and a battery of two dry cells connected in series.

Procedure. Connect up the instruments and bell. Connect to the battery at "E". Hold the hammer away from the bell to keep the current steady. Read volts and amperes and calculate the resistance ohms by the formula:—

$$\text{ohms} = \frac{\text{volts}}{\text{amperes}}$$

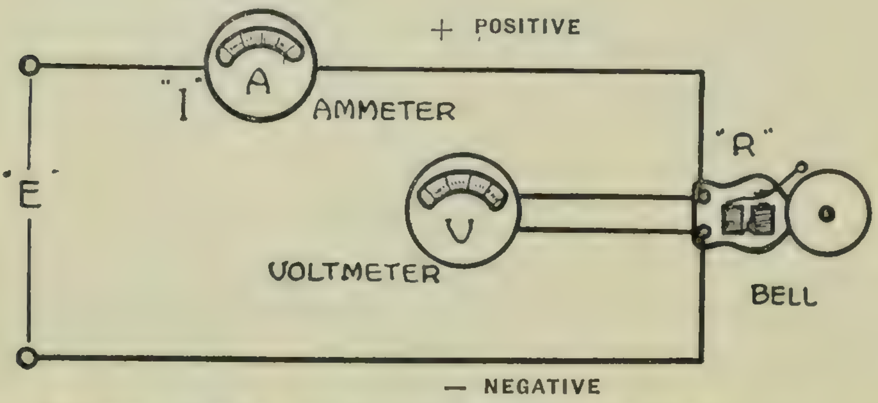


Fig. XLIV. Diagram showing method of measuring resistance of an electric bell.

LESSON.

There are three quantities which must be known in order to understand the conditions in an electric circuit:—

1. **The Electric Current.** This is measured with an ammeter which is placed in the line so that all the current to be measured passes through the instrument.
2. **The Voltage.** This is measured with a voltmeter which is connected across the line, i.e., one wire connected to the positive and the other to the negative line.
3. **The Resistance.** The unit of resistance is called the "ohm". Ohm meters are not very common. Resistance is generally determined by using an ammeter and a voltmeter, and calculating the resistance by the formula:—

$$\text{ohms} = \frac{\text{volts}}{\text{amperes}} \quad \text{or} \quad R = \frac{E}{I}$$

Where R= Resistance in ohms.
E= Volts.
I= Amperes.

Resistance is the opposition offered by electric conductors to the flow of electric current through them. All conductors have some resistance. The resistance of the electric bell is in the copper wire which is wound around the magnet spools. So we see that, although copper wire is a good conductor, it also has resistance.

The resistance of electric wires depends upon three things:—

1. The length—the longer the wire the greater the resistance.
2. The size—The bigger the wire the smaller the resistance.
3. The material—The resistance of any given wire depends upon the material it is made of, e.g., copper, aluminum, iron, etc.

JOB XLV. THE ELECTRIC STOVE.

Proposal. To observe the time taken to boil water on a 660 watt heater.

Requirements. One measuring cup, one tin kettle, 660 watt stove.

Procedure.

1. Connect up stove and allow a few minutes to heat up.
2. Put one quart of cold water in kettle and place on stove—making a note of the time.
3. Watch the water until it boils violently and take the time again.
4. Repeat, using one pint of water.
   If you have time, do the two experiments twice and take the average time.

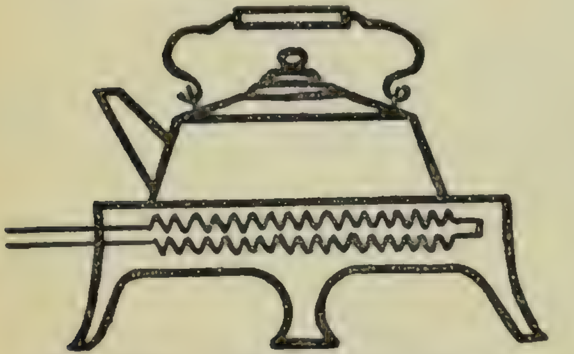


Fig. XLV. The Electric Stove.

LESSON.

Cooking by electricity is a very recent advance in electrical applications. It was always thought impractical but with the production of efficient heating elements and baking ovens, electric cooking has become quite popular. One of the most expensive operations, however, is boiling water. For this reason one should never put more water on the stove than is required for use.

An electric heating element is merely a wire made of very high resistance alloy. When the current passes through it, it becomes red hot. In this way electrical energy is converted into heat energy. The principal effects produced by electricity are magnetism, mechanical energy, chemical energy and heat energy.

The power delivered to the stove is measured in watts. To find the watts, multiply volts by the amperes. To find the energy consumed in kilowatt hours, use the formula:—

$$\text{K.W.H.} = \frac{\text{Watts x hours}}{1000}$$

If a 660 watt stove is operated for 20 minutes, i.e., 1/3 hour, the kilowatt hours would be—

$$\text{K.W.H.} = \frac{660 \times 1/3}{1000} = .22\ \text{K.W.H.}$$

If electricity costs 5c per K.W.H., the cost of operating for 20 minutes would be .22 x 5 = 1.1c.

QUESTIONS.

1. What produces heat in an electric stove?
2. What are the principal effects produced by electrical energy?
3. When boiling water by electricity, why should the quantity be kept as small as possible?
4. Make an estimate of the time required to boil a gallon of water on a 660 watt stove.
5. How many watts are taken by a stove that takes 10 amperes when connected to the 110 volt lighting circuit?
6. What is the cost of operating a 1200 watt stove for three-quarters of an hour if electrical energy costs 3c per K.W.H.?

JOB XLVI. KILOWATT HOUR METER READING.

Proposal. To read a K.W.H. Meter.

Requirements. The dial from a kilowatt hour meter. (Sometimes these can be obtained from old meters from the power company); or, draw a few cards in ink as shown in sketch, using pencil for drawing the pointers, which can be changed as desired.

Procedure. Study the register dials. Read from right to left. (Instructor will tell you where to set or draw pointers before reading). The right hand dial reads units; the next tens; the third hundreds; and the fourth thousands. Practise on as many as possible (at least ten).

Note: To find actual consumption of electricity, two readings must be taken, one at the beginning of the period of use and one at the end, then subtract the first from the second reading.

If possible, take two readings from your meter at home, one at the beginning and one at the end of a seven-day period, and find the consumption during that time.

LESSON.

The kilowatt hour meter is an instrument which measures the total electrical energy delivered to a house (or other circuit) in a given interval of time. Readings are taken at the beginning and at the end of the interval, say one month, and the difference in the readings gives the consumption in kilowatt hours. All meters are tested by the government inspector before being installed. After testing he places his seal on it. This is the consumers' safeguard.

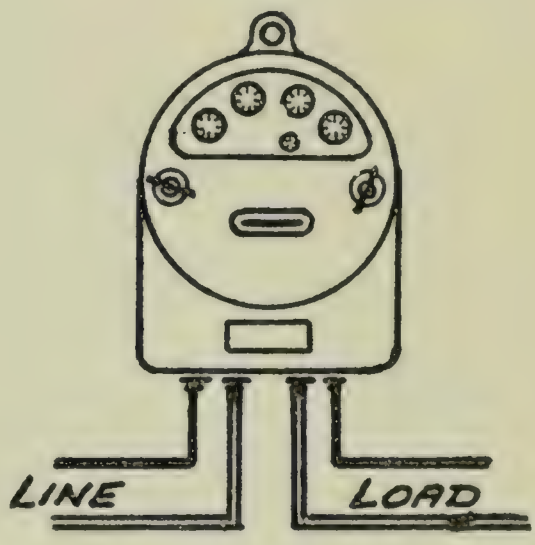


Fig. XLVI. The Kilowatt Hour Meter.

Suppose a meter reads 1945 K.W.H. at the beginning of the month and 1982 K.W.H. at the end. The consumption would be 1982 — 1945 = 37 K.W.H.

If electricity costs 5c per K.W.H., the bill would amount to 37×.05=$1.85.

QUESTIONS.

1. What does the kilowatt hour meter measure?
2. How is the actual consumption determined?
3. In what way is the public protected against inaccurate meters?
4. If a meter reads 6732 at the beginning of the month and 6759 at the end, what would be the **kilowatt** hours consumed?
5. At 4½¢ per **kilowatt** hour, what would be the amount of the bill for the consumption in the last question?

JOB XLVII. WIRE GAUGING.

Proposal. To gauge the size of a number of samples of copper wire.

Requirements. A B. & S. Wire Gauge, a board on which are fastened a number of samples of copper wire of different sizes, each one numbered.

Procedure. Gauge each of the wires on the board. Make a list of the different wires by number, the B. & S. size, and diameter of each. Now look up the wire tables and find the amperes each will carry. Enter these values in a fourth column.

LESSON.

The size of wires on the American Continent is generally measured by the Brown & Sharpe Standard Gauge also called the American Wire Gauge. Although different thickness and material may be used for different purposes the gauge measures the actual size of the copper wire. No. 40 is the smallest size on the gauge and No. 0 is the largest. Larger sizes of wire are also made. They are known as 00, 000, 0000.

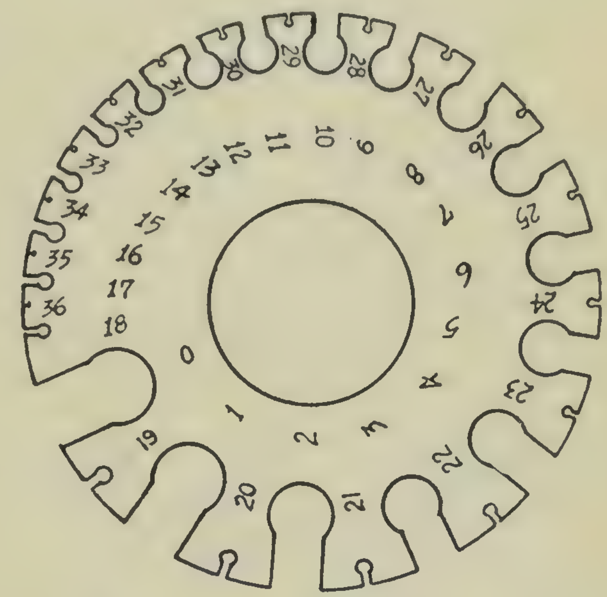


Fig. XLVII. The Wire Gauge.

Wire sizes are also given in **circular-mils.** Thus No. O wire is .324 inches diameter, or 324 mils, and its area in **circular-mils** is 324 x 324 = 105,976 circular-mils. A mil is .001 inch. The standard unit of wire is called the **circular-mil foot** which is a wire .001 inch diameter (1 mil) and one foot long.

The amount of current that a wire can carry depends upon the size and covering of the wire. No. 14 rubber-covered wire can safely carry 15 amperes, although in most cities it is limited to 10 amperes. If a wire carries more than its capacity, it is liable to heat and destroy the insulation, or even cause a fire.

QUESTIONS.

1. What is the standard wire gauge?
2. Which is the larger wire—No. 6 or No. 10?
3. What size wire is used for branch lighting circuits?
4. What current is allowed in the wire of question 3?
5. What is the danger of excess current in insulated electric wires?

JOB XLVIII. THREE HEAT STOVE SWITCH.

Proposal. To connect a three heat switch to two lamps so as to illustrate the operation of the elements of an electric hot plate.

Requirements. One three heat electric switch, two lamps of the same size, two lamp receptacles, lamp cord and plug.

Procedure. Study the diagrams and read the lesson carefully. Using the two lamps in place of the two elements, connect the switch in the circuit. Have your circuit checked by the instructor before testing out, as you may blow a fuse. Use the lamp cord and plug to connect to the lighting circuit.

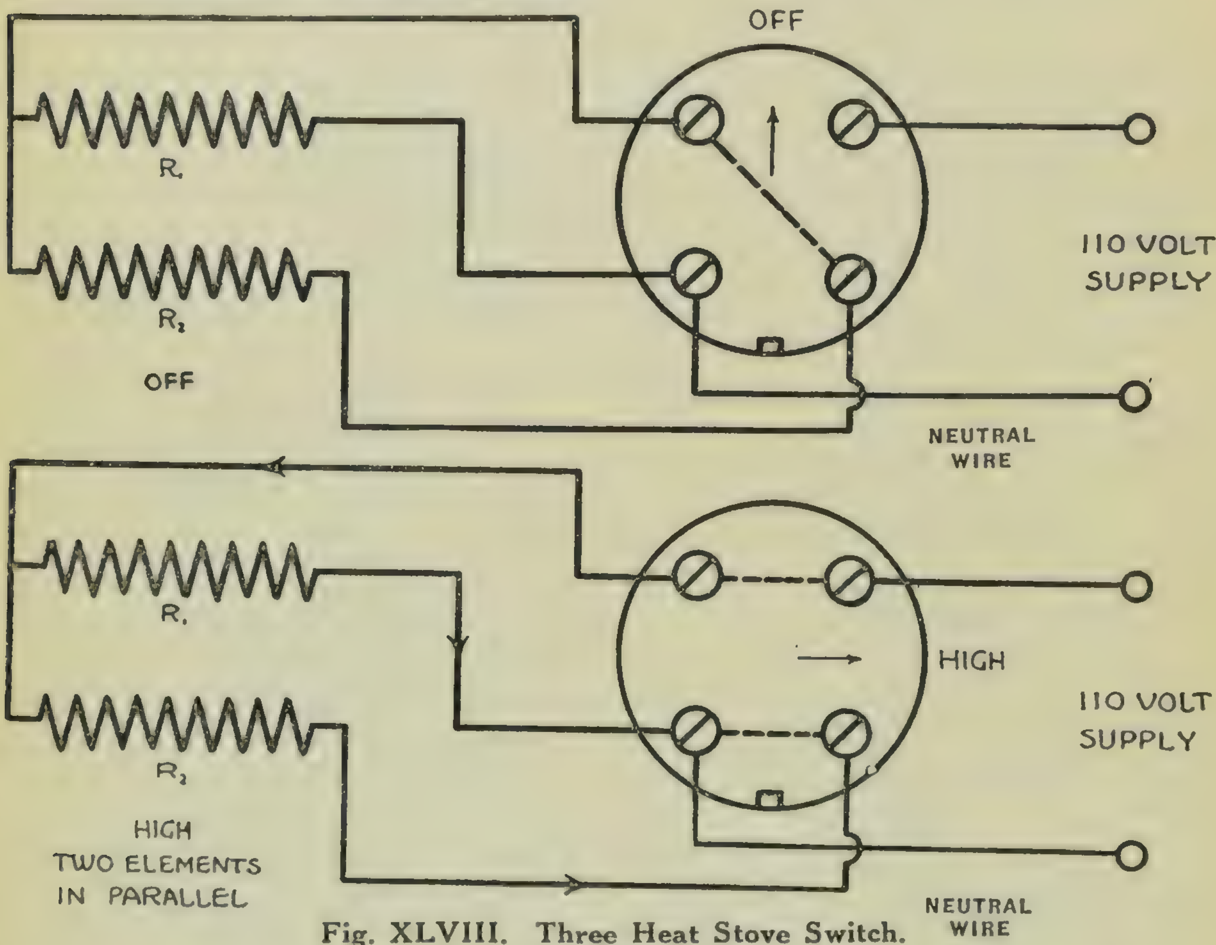


Fig. XLVIII. Three Heat Stove Switch.

LESSON.

An electric stove plate is composed of two separate heating elements. These elements are coils of high resistance wire. In order to obtain three different heats the elements are connected as follows:—

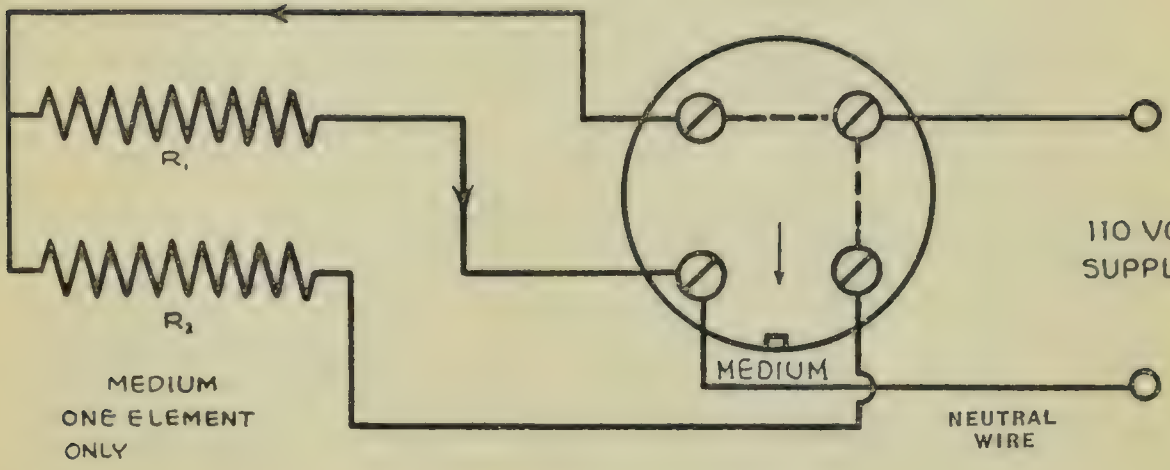
1. For high heat they are in parallel.
2. For medium heat one element only is used.
3. For low heat they are both connected in series.

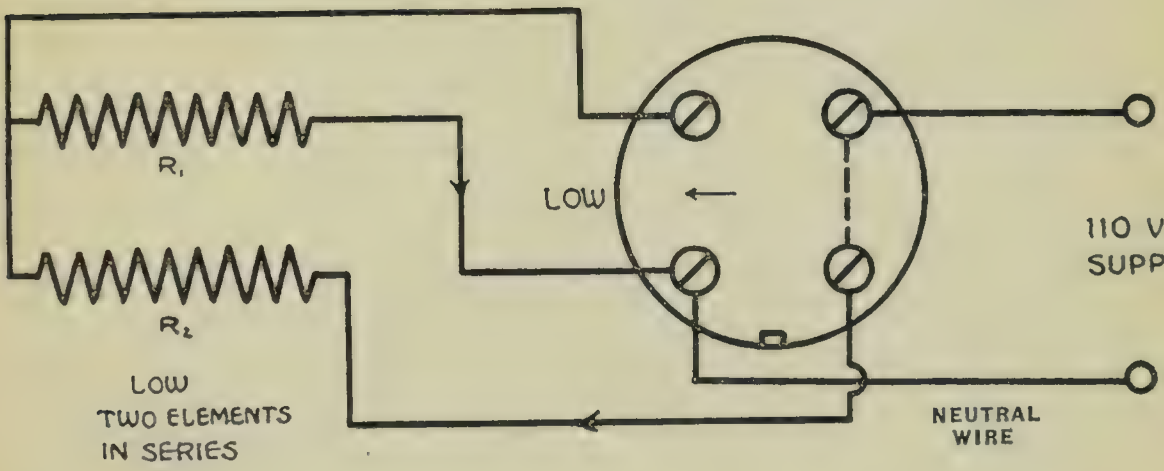
To accomplish this, a special switch is used having four terminal posts. The changes are made for each position by giving the switch a quarter turn. The connections for each position of the switch are shown in the diagrams. If you trace out the path of the current you will see how the above conditions are fulfilled. The medium position is the most difficult one to follow, where one of the elements is short circuited and not in use.

QUESTIONS.

1. Of what is an electric hot plate composed?
2. How are elements connected for high heat? For medium heat? For low heat?

THREE HEAT STOVE SWITCH





JOB XLIX. THE THREE WIRE LIGHTING SYSTEM.

Proposal. To construct a three wire system of lighting.

Requirements. Six lamps 1½ volts each, two dry cells, six miniature lamp receptacles.

Procedure. Connect lamps and cells in a series-parallel arrangement as shown in the diagram. Turn on the first three lamps in parallel, one at a time, by screwing into socket. Now turn on the other three in the same manner. Notice that no matter how many lamps are connected on either side, the brightness does not change. This is the three wire system of lighting.

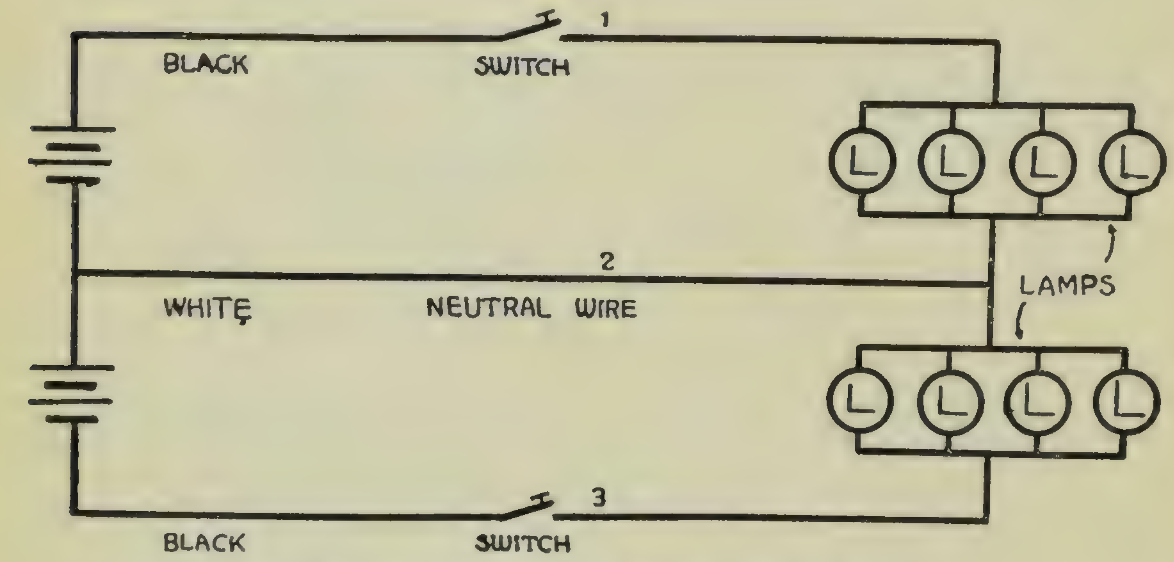


Fig. XLIX. The Three Wire Lighting System.

LESSON.

In large buildings where there is considerable lighting loads the three wire system is used. This method is more economical because it cuts down the amount of wire required by 25%. The middle wire is called the "neutral", and is always white covered. There are no fuses or switches in this line. It is one continuous wire from the outside line to lamp and must be "grounded". The other two are called the "outside" wires, and in them the switches and fuses are placed.

QUESTIONS.

1. Make a sketch of a simple three wire lighting system.
2. What is the middle wire called?
3. In what line are the switches and fuses placed?
4. Which of the three wires is "grounded"?
5. What does "grounded" mean?

JOB L. GAS ENGINE IGNITION.

Proposal. To wire up a single cylinder gas engine ignition system.

Requirements. Three dry cells, one spark coil, one spark plug, one small engine model, wire and staples, one switch. Engine model can be cut out of sheet metal, and painted as shown in sketch. Fold metal at the top so as to make a place for the spark plug.

Procedure. Wire up engine as shown in the sketch. If sheet metal model is used, this work can be done on wiring board. Test the operation by making contact at the switch or "timer."

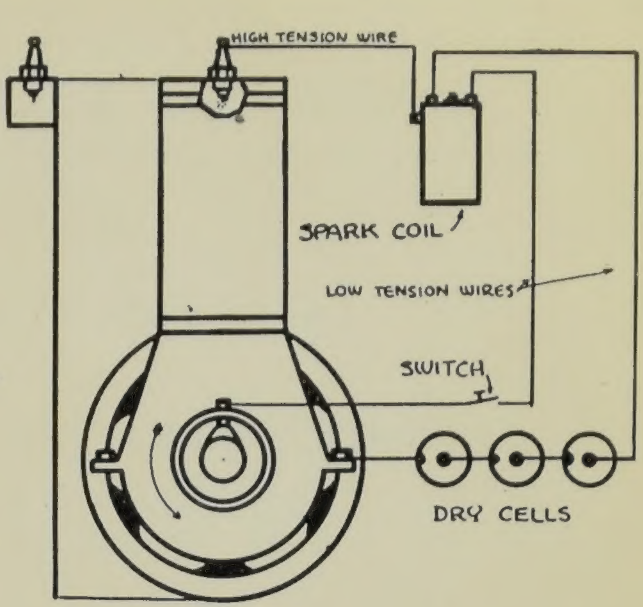


Fig. L. Gas Engine Ignition.

LESSON.

Ignition means "setting fire to." In the gas engine, gasoline vapour and air are sucked into the cylinder and compressed by the piston into the upper end. At this moment the "timer" switch is closed and the resulting spark ignites the gasoline vapour. The explosion forces the piston down. The "timer" is a mechanically operated switch which causes the spark to take place at the proper moment. The spark plug provides a properly insulated "gap" inside the engine cylinder for the spark to jump. The spark coil must be used because the voltage of the battery is not high enough to make the spark jump the gap. This coil "steps up" the voltage in much the same way as a lever can be made to cause a large mechanical force by a comparatively small pressure at one end.

Automobile engines have four, six, eight or more cylinders. In order to "fire" them all by the one coil an automatic connector is used called the "distributor." This connects the "high tension" wire to each cylinder in the proper order and at the proper time.

QUESTIONS.

1. What is meant by the word "ignition"?
2. What is a spark plug?
3. Explain the operation of the "timer"?
4. Why must a spark coil be used?
5. What is the purpose of the "distributor" on the automobile engine?

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